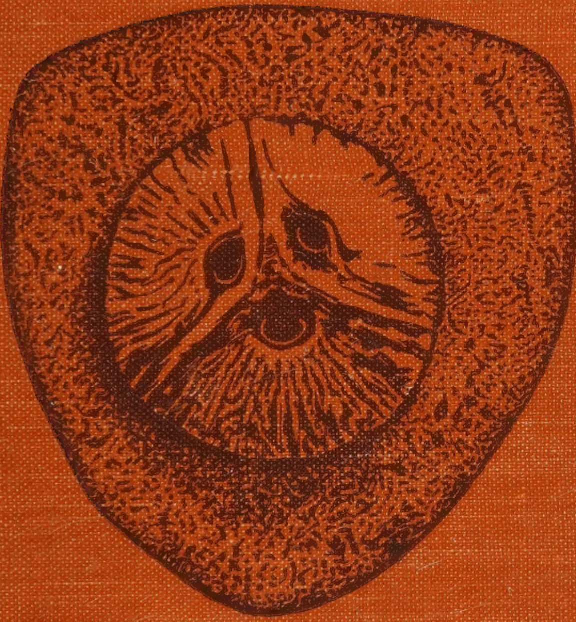
THE COCONUT PALM



H. C. SAMPSON

1930

Imperial Bureau of Soil Science.
WITHDRAWN

@ BL 0020871

Digitized by the Internet Archive
in 2022 with funding from
Kahle/Austin Foundation

https://archive.org/details/coconutpalm0000hcsa

THE COCONUT PALM.

The coconut.

ntispiece.

@ DL

THE
COCONUT PALM

THE SCIENCE AND PRACTICE OF COCONUT CULTIVATION

8313

BY

H. C. SAMPSON, C.I.E., B.Sc.

From the Bas-Reliefs of Bayon Temple—IXth Century.
Ankor, Cambodia.

LONDON:
JOHN BALE, SONS & DANIELSSON, LTD.
Oxford House
83-91, GREAT TITCHFIELD STREET, OXFORD STREET, W.1.

1923

634.6

PRINTED AND MANUFACTURED IN GREAT BRITAIN.

PREFACE.

I WISH to take this opportunity of showing my appreciation to the Government of Madras for permission to write this book and to utilize information and illustrations officially obtained.

I also wish to acknowledge the co-operation and help rendered to me by my colleagues of the Madras Agricultural Department, more especially Dr. R. V. Norris, Government Agricultural Chemist, Madras, who together with his assistants has done all the analyses, &c., which are included in the book.

Further, I wish to acknowledge the work of M. R. Ry. C. Ranganatha Mudeliar, Avl, Artist in the Madras Agricultural Department, who has prepared most of the original paintings and drawings reproduced in the text.

I am indebted to Monsieur P. G. Jeannerat for the illustration on the title page.

H. C. SAMPSON.

CONTENTS.

PAGE
Introduction xiii

Part I.

THE COCONUT PALM.

The Root System 1
The Stem 29
The Crown 34
The Leaf 43
The Flowering Branch and the Flower 50
The Fruit and its Development 65
The Germination of the Seed and the Development of the Seedling 78

Part II.

PLANTATION MANAGEMENT.

The Selection of a Site for a Plantation 87
Seed and Seed Selection 96
The Nursery or Seed Bed 107
Preparation of the Land for Planting 114
Cultivation 127
Care of the Young Plantation 142
Catch Crops 149
Cover Crops 154
Management of the Grown Plantation 159
Manuring 170
Care of the Old Plantation 211

Part III.

COCONUT PRODUCTS.

Coconut Products 217
The Manufacture of Copra 218
Coconut Oil 226
The Manufacture of Coir 230
Tapping 235
Minor Industries 243
Index 245

LIST OF ILLUSTRATIONS.

PAGE

Frontispiece—The Coconut

Plate I.—The Root System of the young Coconut, nine months after planting out 18

Plate II.—The Root System of the young Coconut, two years after planting out 20

Plate III.—Fig. 1—The Root System of a grown Tree. Fig. 2—A surface "feeding root" 22

Plate IV.—Roots of the Coconut Palm 24

Plate V.—Transverse section of the Root of the Coconut Palm. (magnified) 26

Plate VI.—Stem of the Coconut Palm—lower part. Showing leaf scars when the tree was coming into bearing 30

Plate VII.—Stem of the Coconut Palm. Showing leaf scars on the bearing portion of the stem 30

Plate VIII.—Cross section through the bud showing leaf arrangement—young leaves in the bud 40

Plate IX.—A Bad Type of Tree. Note the weak leafstalk, the long fruit branch stalk and the leaf bracket unable to support the weight of the bunch... 44

Plate X.—A Bad Type of Tree. Note the long fruit branch stalk and the narrow leafstalk. The bunches have slipped off the supporting leafstalk bracket 44

Plate XI.—A Good Type of Tree. Note the short fruit branch stalk and the bunches well supported by the leafstalk bracket 44

Plate XII.—The Leaf of the Coconut Palm (with scale in feet)... 46

Plate XIII.—Sections through the Leafstalk and Midrib ... 46

Plate XIV.—The Attachment of the Leaflets to the Midrib ... 46

Plate XV.—The Development of the Bud of the Flowering Branch 50

Plate XVI.—The Coconut Flower. Fig. 1—A part of the Flowering branch. Fig. 2—The Female flower bud: (*a*) in section; (*b*) entire. Fig. 3—The Male flower. Fig. 4—(*a*) As the branchlet appears when the female flowers open; (*b*) different aspects of the Female flower 56

PAGE

PLATE XVII.—The Development of the Coconut from the Ovule to the ripe fruit (longitudinal section) 68

PLATE XVIII.—The Development of the Coconut from the Ovule to the ripe fruit (transverse section) 68

PLATE XIX.—Colour variation of the Coconut fruit 74

PLATE XXA.—The Germination of the Coconut. Figs. 1 to 3—Different views of the ripe nut. Fig. 4—One month after germination has commenced 80

PLATE XXB.—The Germination of the Coconut. Fig. 5—One month after germination has commenced. Fig. 6—Two months after germination has commenced. Fig. 7—Three months after germination has commenced: (*a*) The scar on the lowest scale leaf where this forced its way through the "soft eye." Fig. 8—Four months after germination has commenced 80

PLATE XXC.—The Germination of the Coconut. Fig 9—Four months after germination has commenced. Fig. 10—Do. Longitudinal section through the "apple" and the plumule 82

PLATE XXD.—Germination of the Coconut. Fig. 11—Five months after germination has commenced. Note the fibrous branching roots which ramify through the husk 82

PLATE XXE.—Germination of the Coconut. Fig. 12—Five months after germination has commenced. Figs. 13 and 14—Six months after germination has commenced 82

PLATE XXF.—Germination of the Coconut. Fig. 15—Eight months after germination has commenced; (*b*) is the reverse side of (*a*). Fig. 16—Nine months after germination has commenced; (*b*) is the reverse side of (*a*)—note the young roots just emerging; (*c*) note how the "apple" has consumed the "meat" 82

PLATE XXI.—Leaf of the Coconut seedling commencing to split... 84

PLATE XXII.—Section through a young Coconut Tree which has been "weaned," showing the development of the "cabbage" 84

PLATE XXIII.—Seedling attacked by the fungus, *Pestalozzia palmarum* 108

PLATE XXIV.—A Good Type of Young Plant. Note the thick short leafstalk and the wide leaflets arranged close together ... 111

PLATE XXV.—A "Leggy" Young Plant. Note the long slender leafstalk and the narrow leaflets arranged far apart 111

PLATE XXVI.—Preserving the Soil Mulch. A bullock cultivator at work 140

PAGE

Plate XXVII.—Coconut trees reaching out to the Light from the shade of a Banyan tree 153

Plate XXVIII.—The butt ends of Coconut leaves stacked for sale as fuel 160

Plate XXIX.—Husking Coconuts 168

Plate XXX.—Percentage of Dry Matter to Total Weight of the Green Plant 186

Plate XXXI.—Percentage of Ash in Dry Material 187

Plate XXXII.—Percentage of Potash (K_2O) in Ash 188

Plate XXXIII.—Percentage of Phosphoric Acid (P_2O_5) in Ash 189

Plate XXXIV.—Percentage of Lime (CaO) in Ash 190

Plate XXXV.—Percentage of Magnesia (MgO) in Ash ... 191

Plate XXXVI.—Coconut tree which has not been manured for at least five years. Showing a segment of the ground where the surface roots have been washed out to a radius of 8 feet. The effects of previous manuring are clearly evident around the base of the bole 206

Plate XXXVII.—Coconut tree manured to a radius of 4 feet. Showing a segment of the ground where the surface-feeding roots have been washed out to a distance of 6 feet 206

Plate XXXVIII.—Coconut tree manured to a radius of 8 feet. Showing a segment of the ground where the surface-feeding roots have been washed out to this distance 208

Plate XXXIX.—Coconut tree manured to a radius of 12 feet. Showing a segment of the ground where the surface-feeding roots have been washed out to this distance. 208

Plate XL.—Regeneration. A plantation underplanted with Seedlings 212

Graph A.—Showing the Seasonal Variation in the number of female flowers formed in each consecutive bunch and the number which ripen fruit (average of 25 regular bearing trees) 57

Graph B.—Showing the Seasonal Variation in the number of nuts which set in each consecutive bunch (average of 100 regular bearing trees) 62

INTRODUCTION.

The coconut belongs to the family of palms, which in their turn belong to the lower group of flowering plants called Monocotyledons.

With few exceptions, the family of palms includes the trees of the Monocotyledonous group and these differ from the trees of the upper (Dicotyledonous) group in several main characteristics.

The palms have not the power of making secondary thickening. They have no bark and no cambium (the living and growing tissues between the bark and the wood). Thus when once the stem is formed it never alters in thickness except to shrink slightly as the stem gets old. The same is true of the roots. There is no tap root on the palm, and the roots when once formed never grow in thickness. In order to maintain the plant, therefore, the palm has an entirely different root system from that of dicotyledonous trees. Very few of the palms ever form branches and very few of them ever form vegetative buds on the stem. The only buds which they do form are those which develop into fruiting branches. The leaves, therefore, have to take the place of the branches, and in consequence these are usually large. The only vegetative buds are those at the apex of the stem, and if these are killed the whole stem dies. In the case of some palms, such as the

Talipot, this vegetative bud changes into a fruiting bud when the tree reaches a certain age, and the result is that when the palm has flowered and fruited it dies. Since the life of the palm depends on the existence of this bud it is very carefully protected.

The palms yield perhaps more products of use to the human race than any other family of plants, and the coconut is probably the most useful of these in that it produces oil, fibre, sugar and alcohol ; besides many other products which are of use in the country of their origin. In Sanskrit it is called Kalpa Vriksha, the tree which provides all the necessities of life.

PART I.

THE COCONUT PALM.

THE COCONUT PALM.

THE ROOT SYSTEM.

A STUDY of the root system of the coconut is of great interest, and a knowledge of this is of special importance to any one who wishes to grow this crop. The permanent success or failure of a plantation is dependent on this knowledge.

The coconut palm, being a monocotyledon, does not form a tap root. It produces and continues to produce throughout its life, roots from the base of the bole or stem. These are the main roots of the tree. They are very uniform in size, being about three-eighths to half an inch in diameter according to the vigour of the tree. They are also very long lived. The number which exist on a tree vary, in consequence, with the age of the tree. This number also varies with the fertility of the soil and the consequent girth of the bole. On the poor sandy soils of the Malabar Coast these may vary from 1,500 to 2,500 in the case of trees aged about twenty-five years, while Copeland states that in the Philippines the number of roots counted on a bole usually vary from 4,000 to 7,000.

These main roots are the arteries along which the crude sap, taken in from the soil through the absorptive area of the root, is carried. In themselves they are of little use in absorbing plant food from the soil, since only a small area immediately behind the growing end is capable of doing this. Under certain conditions, however, these main roots are capable of branching. They may form strong branch roots which develop into straight growing roots, much the same in girth as the main root from which they have sprung. Besides these, the main roots are able, under suitable conditions of soil aeration and drainage, to form a large number of branch "feeding roots," which in their turn branch freely again and again, thus forming in the aggregate a large absorptive surface through which plant food is taken in by the plant from the soil. These branch roots are, however, short-lived and have to be frequently replaced by fresh branchlets.

The number of roots which a tree forms is greatly in excess of the number actually required at any one time by the tree. A large number of these are, so to speak, held in reserve and are ready to take up work when required to do so. At one time of course they must have been active, but from some cause or other the growing end has died and no effort has been made on the part of the tree to replace it. Such a reserve is essential in the case of a monocotyledonous tree, since these have not the power which is possessed by ordinary trees either of increasing in girth or of healing over any wounds which they receive. Thus if a root is damaged and the end of it dies, either it will form a fresh branch root from behind the point of injury to replace the main root, or else another dormant root will commence to grow and thus take its place.

There is also a great variation in what may be termed the root habit of the coconut palm. Besides the variation in the rate of new root production, there is the variation in the capacity to form branch rootlets, and also in the direction in which roots grow through the soil. In the case of a young tree, the actual number of main roots formed is an indication of the development of the crown. But the converse of this is not always true. That is to say :—a young tree which has a large number of main roots has a correspondingly well-developed crown, but a young tree may have a well-developed crown and only a small number of main roots. If this latter is the case, then it will be found that the main roots have branched very freely, which means that each main root draws on a much larger absorptive area than is the case where free branching has not taken place.

There is a very marked variation in the vertical direction taken by the roots of this palm. Some trees will send their roots obliquely into the soil, while in others the greater number of roots will grow in a much more horizontal direction. In all probability it is for this reason that the practice has arisen to obtain seed nuts from trees grown under similar soil conditions to those on the area required to be planted up. Where soil aeration is not good, it naturally follows that those trees whose roots grow in a more horizontal direction have a better opportunity to develop heavy crops of fruit than a tree where the direction of the roots is oblique, as in the latter case these more deeply seated roots would die or become inactive where drainage and soil aeration were bad. Again, on a free drained light soil, trees whose roots grow in an oblique direction will probably give the heaviest crops, since such trees are not only much better protected against great changes in the moisture content of the soil, but they have more range for the development of their root system in their search for plant food. It does not necessarily follow that because the parent tree has a particular root system, its progeny will develop the same. All coconuts are the product of cross fertilization, and therefore no tree has or can have a pedigree, which would enable it to breed true to its female parent type.

It is very largely on account of these variations in the root habit and in the rate of new root production, that there is such a difference in the bearing capacity of individual trees. Sixty nuts per tree per annum is generally considered a fair average yield, yet every coconut grower knows that certain trees in his plantation will regularly produce more than double this number, while other trees grown under identical conditions will not produce even half this average number.

It is more than probable that a further study of the root development will enable the grower to make a much more careful selection of seedlings for planting when these are lifted from the nursery, and this in its turn will raise the average number of nuts per tree per annum.

The following studies of the root development, though by no means complete, indicate that this is so, but before giving these it is necessary to describe how the root system is developed.

If a germinating coconut be examined, it will be seen that the shoot has forced its way through the "soft eye" of the seed nut, and has then made its way through the fibrous husk of the fruit towards the sky. From the base of this shoot, outside the shell, but within the husk of the seed nut, a single main root is first formed, which commences to grow through the fruit husk till finally it forces its way into the soil. Fine fibrous branch roots are given off from this main root, which ramify through the husk and from which they extract nourishment—more especially salts of potash, which are required in abundance by the rapidly growing tissue, and also by the leaves as soon as these expand. Fresh main roots are formed at intervals at one side or other of the earlier formed roots, and immediately adjacent to them, and this formation of main roots will continue till a complete circle of emerging roots is formed, which may be a year or eighteen months after germination has commenced. By this time the shoot will have spread its leaves and the base of the stem will have commenced to swell.

As the seedling gets older, fresh roots are formed from the stem between the leaf scars of leaves which have died. The base of the stem continues to swell as new and larger leaves are formed, thus expanding the area from which new roots can be produced. As this stem swells it forces itself further into the ground.

The young tree does not commence to form a visible stem till after some considerable time. This time varies with the fertility of the soil. It may be only three years and it may be as much as seven or eight. It will not do so till it has reached a stage when it is capable of producing full-sized leaves. During this time the stem has been increasing in size rapidly in what will be the base of the future tree, and this base when fully developed will have about twice the girth of the stem of the grown tree. It is only when the tree has reached this stage of development that the shoot commences to grow upwards and forms the vertical stem.

It is this swollen base of the stem which is ordinarily capable of producing roots. There is, however, a definite root-producing area confined to the basal 1½ to 2 feet. Above this, even though the stem be buried in the ground, the stem will not ordinarily produce roots. When the tree is aged and has commenced to decline, the base of the bole commences to decay and the tree may then produce roots above the normal root-producing area in its endeavour to maintain life.

Even when the seedling has formed four to five roots, which have emerged through the husk, there is a marked variation in the direction of growth. In some cases these emerge through the sides of the seed nut, close under the surface of the soil, while in others these emerge from the bottom of the seed nut where this rests in the ground.

Apart from the rapidity with which nuts germinate—some only take three months before the shoot emerges through the husk and others take as long as nine months—there appears to be a great variation in the rate of root production even at this early stage in the growth of the plant. This is shown in the following tables, where twenty seedlings have been examined when the development of the shoot was practically the same. This examination was made exactly four months after the seed nuts had been sown in the nursery :—

In the first table where the parent trees were grown on heavy backwater soil the rate of root production, as one would expect from condition of poor soil aeration, is much more rapid than in the case where the seed nuts were obtained from trees grown on well-drained sandy soil. Not only are the number of roots more (3·05 as compared with 2·25), but the length of the roots is much greater as measured from the point of emergence through the husk.

TABLE I.—SEEDLINGS RAISED FROM NUTS OBTAINED FROM TREES GROWN ON HEAVY BACKWATER SOIL.

No.	Length of shoot in inches (protruding beyond the husk)	Number of roots which have grown through the husk	Length of each root beyond the husk (in inches)				Total length of roots beyond the husk (in inches)
			I	II	III	IV	
1	1·9	3	14·8	6·2	2·2		23·2
2	1·2	4	5·9	4·4	0·6	0	10·9
3	1·2	4	9·5	6·8	1·1	0·8	18·2
4	1·5	1	5·5				5·5
5	1·1	3	4·8	1·2	0		6·0
6	1·0	2	7·5	2·2			9·7
7	0·5	4	16·2	7·6	0	0	23·8
8	0·5	4	9·9	8·1	2·3	1·3	21·6
9	0·5	4	9·5	8·0	4·9	7·6	30·0
10	1·4	4	18·4	17·0	12·6	8·0	56·0
11	1·9	2	8·6	2·8			11·4
12	0·8	2	11·1	2·1	0		13·2
13	0·8	3	14·2	7·5	3·9		25·6
14	0·5	2	13·4	4·5	0		17·9
15	0·2	3	14·4	6·1	1·6		22·1
16	0·8	3	12·2	2·5	1·1		15·8
17	Shoot just visible	4	17·3	5·9	4·8	2·1	30·1
18		4	6·0	5·7	1·1	0	13·6
19		4	14·0	3·5	1·2	0	18·7
20		1	5·6				5·6
Average	0·79	3·05					18·94

In each table there is a great deal of variation in the case of individual seedlings (compare Nos. 4 and 10 in

Table I and Nos. 3 and 18 to 20 in Table II). There has been no opportunity up to the present to follow up the root development of these particular seedlings, but in the case of plants of two years' growth after transplantation, the following table shows a large amount of variation in the number of main roots formed. The rate of new root production, after the rainy season had set in, shows similar variation. It is to be noticed here that the development of the crown, in general, corresponds with the number of main roots formed :—

TABLE II.—SEEDLINGS RAISED FROM NUTS OBTAINED FROM TREES GROWN ON COAST SANDY SOIL.

No.	Length of shoot in inches (protruding beyond the husk)	Number of roots which have grown through the husk	Length of each root beyond the husk (in inches)				Total length of roots beyond the husk (in inches)
			I	II	III	IV	
1	1·7	3	12·4	3·0	0·5		15·9
2	1·8	2	17·8	4·5			22·3
3	1·5	4	16·4	7·8	4·7	0·8	29·7
4	1·8	2	5·7	0·3			6·0
5	1·7	2	4·9	1·0			5·9
6	1·1	2	5·7	0·3			6·0
7	1·3	2	9·7	1·7			11·4
8	1·3	2	15·0	1·9			16·9
9	1·3	3	18·0	4·2	3·3		25·5
10	1·3	4	14·7	5·2	4·0	3·5	27·4
11	1·0	2	15·4	3·9			19·3
12	0·8	2	7·7	6·7			14·4
13	1·1	3	8·6	6·7	4·6		19·9
14	0·6	4	16·4	1·6	1·1	0·8	19·9
15	0·7	1	13·3				13·3
16	0·5	3	13·5	3·6	2·2		19·3
17	0·8	4	8·3	7·4	3·6	0	19·3
18	Shoot just visible	0					0
19	0·4	0					0
20	0·4	0					0
Average	1·07	2·25					15·34

Serial No.	Number of green healthy leaves	Length of the last two leaves				Number of old roots	Number of new roots formed since the rains began	Total number of roots
		feet	inches	feet	inches			
1	7	9	7	10	3	99	14	113
2	7	9	10	10	8	89	16	105
3	7	9	10	10	7	92	12	104
4	7	8	8	9	7	92	12	104
5	7	11	2	11	10	91	12	103
6	7	9	6	10	5	90	12	102
7	7	9	11	10	6	79	23	102
8	7	10	5	12	0	77	8	85
9	7	10	6	10	8	72	12	84
10	7	10	0	10	8	61	6	67
11	7	7	7	8	9	55	10	65
12	7	8	6	9	8	58	5	63
13	6	10	0	11	10	114	16	130
14	6	10	0	11	0	110	15	125
15	6	10	5	11	0	93	11	104
16	6	9	4	10	1	79	16	95
17	6	8	5	9	3	79	14	93
18	6	9	7	10	7	77	13	90
19	6	9	2	9	10	76	13	89
20	6	8	10	9	9	74	13	87
21	6	9	7	10	8	78	9	87
22	6	7	2	7	9	64	12	76
23	6	9	2	10	3	63	13	76
24	6	11	2	7	9	53	14	67
25	5	11	8	12	3	111	11	122
26	5	7	10	8	11	79	20	99
27	5	8	5	9	6	84	9	93
28	5	8	9	9	6	76	15	91
29	5	8	5	9	10	75	15	90
30	5	9	7	10	10	77	9	86
31	5	7	11	9	1	68	12	80
32	5	9	0	10	3	70	10	80
33	5	8	10	9	3	65	15	80
34	5	8	0	9	2	63	12	75
35	5	11	2	7	9	53	14	67
36	5	8	9	9	9	58	8	66
37	5	9	7	10	2	54	10	64
38	4	7	0	7	10	58	13	71
39	4	7	4	8	4	52	15	67
40	4	4	9	5	8	41	9	50
41	3	5	4	6	5	36	9	45
42	3	4	2	4	10	34	2	36
43	3	4	10	5	8	18	1	19

In order to ascertain whether the capacity of a bearing tree to produce fruit is in any way dependent on the number of main roots formed, six bearing trees, aged about twenty to twenty-five years, were selected for examination. Three of these had a record of being very shy bearers, as though the plant were easily exhausted after bearing a small number of fruit ; and three had a record of being regular bearing trees. In each case one-fifth of the root-bearing portion of the bole was vertically exposed, and the number of roots given off at each six-inch depth counted. The total in each case multiplied by five gives the approximate number of roots on each plant. The trees selected were all grown in the same plantation, and the soil conditions were similar throughout. The portion examined in each case was at the same point of the compass, viz., that from which the prevailing winds blow during the rainy season. The results of the examination are given below.

REGULAR BEARING TREES.

Tree No. II, 40.—During the period covered by these records the tree produced a fresh leaf and bunch on an average of every thirty days, and the stem made 2 feet in growth. Each leaf produced an inflorescence in its axil. Each inflorescence bore female flowers, and only one failed to set fruit. The root-bearing portion of the base of the stem consisted of the basal 1½ feet. The first ½ foot carried 935 roots. The second ½ foot carried 850 roots, and the basal ½ foot, which tapered to a point, carried 350 roots, making a total of 2,135 roots. The bulk of the roots had a distinct downward habit. The following is the cropping record from the commencement of 1918 till October 13, 1920:—

1918 *Crop.*

Number of female flowers in each consecutive bunch :—

												Total	Average
13	12	19	14	17	27	50	17	16	15	17	18	235	20

Corresponding number of ripe nuts harvested :—

7	7	6	7	6	10	10	7	3	1	9	0	73	6·0

1919 *Crop.*

Number of female flowers in each consecutive bunch :—

10	9	14	8	14	18	26	14	14	15	18	160	14·5

Corresponding number of ripe nuts harvested :—

3	2	4	6	2	5	5	11	10	11	11	70	6·4

1920 *Crop* (*up to October* 13, 1920).

Number of female flowers in each consecutive bunch :—

13	23	24	21	27	20	27	26	35	23	25	264	24

Corresponding number of ripe nuts harvested :—

13	14	17	9	9	11	15	4	9	11	15	127	11·5

TREE NO. II, 92.—During the period covered by these records, the tree produced a fresh leaf and bunch on an average of every twenty-four and a half days. Only one inflorescence did not carry female flowers, and with this exception each bunch set some fruit. During this period the stem made 1¾ feet growth. The root-bearing portion of the base consisted of the basal 1 foot 8 inches. The first ½ foot carried 465 roots. The second ½ foot carried 870 roots. The third ½ foot carried 680 roots, and the apex carried 330, making a total of 2,345 roots :—

1918 *Crop.*

Number of female flowers in each consecutive bunch :—

Total Average

11 13 11 0 15 17 16 17 14 21 14 16 19 11 10 205 13·7

Corresponding number of ripe nuts harvested :—

3 3 2 0 4 3 4 7 2 2 1 6 2 7 3 49 3·3

1919 *Crop.*

Number of female flowers in each consecutive bunch ;—

21 23 16 23 20 16 32 28 29 24 25 25 25 307 23·6

Corresponding number of ripe nuts harvested :—

2 7 7 7 12 1 11 10 10 2 8 4 6 87 6·7

1920 *Crop* (*up to October* 14, 1920).

Number of female flowers in each consecutive bunch :—

27 39 37 33 30 29 30 24 35 35 28 33 23 403 31

Corresponding number of ripe nuts harvested :—

7 5 3 4 3 2 11 1 5 12 4 7 11 75 5·8

TREE NO. II, 128.—During the period covered by these records the tree produced a fresh leaf and inflorescence on an average of every twenty-seven days, and the stem made 2½ feet growth. All except three of these inflorescences produced female flowers, and with these three exceptions each bunch set some fruit. The root-bearing portion of the base consisted of the basal 1 foot 10 inches. The first ½ foot carried 855 roots. The second ½ foot carried 750 roots. The third ½ foot carried 630 roots, and the apex carried 170, making a total of 2,405 roots.

1918 *Crop.*

Number of female flowers in each consecutive bunch :—

Total Average

16 14 55 68 69 100 98 58 18 17 13 17 15 16 13 5 592 37

Corresponding number of ripe nuts harvested :—

4 2 6 10 7 11 8 6 7 4 2 3 1 2 3 3 79 5

1919 *Crop.*

Number of female flowers in each consecutive bunch :—

26 42 63 108 99 61 37 46 0 15 17 20 13 17 564 40

Corresponding number of ripe nuts harvested :—

8 8 6 10 8 9 14 6 0 2 4 3 3 5 86 6·1

1920 *Crop* (*up to October* 15, 1920).

													Total	Average
Number of female flowers in each consecutive bunch :—	53	96	67	94	94	55	41	35	0	0	22	17	574	46
Corresponding number of ripe nuts harvested :—	4	9	9	7	12	9	8	12	0	0	4	1	75	6·25

IRREGULAR BEARING TREES.

Tree No. II, 87.—During the period covered by these records the tree produced a fresh leaf and inflorescence on an average of every twenty-eight and a half days, and the stem made 1 foot 4 inches growth. All except one inflorescence produced female flowers. Of the rest, three failed to set any fruit, while ten only ripened one nut each. The root-bearing portion of the base consisted of the basal 1 foot 8 inches. The first ½ foot carried 285 roots. The second ½ foot carried 720 roots. The third ½ foot carried 420 roots, and the apex carried 35 roots, making a total of 1,460 roots.

1918 *Crop.*

													Total	Average
Number of female flowers in each consecutive bunch :—	14	14	19	17	18	18	19	7	8	10	8	5	157	13·1
Corresponding number of ripe nuts harvested :—	2	1	1	3	2	0	4	2	1	1	1	1	19	1·6

1919 *Crop.*

Number of female flowers in each consecutive bunch :—	16	17	30	17	8	15	0	12	9	7	6	8	22	167	13·0
Corresponding number of ripe nuts harvested :—	3	1	3	2	4	8	0	2	2	1	1	3	1	31	2·4

1920 *Crop* (*eight months*).

Number of female flowers in each consecutive bunch :—	21	24	24	21	19	20	22	18	169	21·0
Corresponding number of ripe nuts harvested :—	0	1	2	0	2	2	5	2	14	1·75

TREE No. II, 101.—During the period covered by these records the tree produced a fresh leaf and inflorescence on an average of every twenty-seven and a half days, and the stem made 2 feet 10 inches growth. All except three inflorescences carried female flowers. Of the rest, nine failed to set any fruit, while twelve only set one nut on each bunch. The root-bearing portion of the base of the stem consisted of the basal 1 foot 8 inches. The first ½ foot carried 620 roots. The second ½ foot carried 715 roots. The third ½ foot carried 485 roots, and the apex carried 60 roots, making a total of 1,880 roots.

1918 *Crop.*

Number of female flowers in each consecutive bunch :—

												Total	Average
7	0	15	0	20	19	11	17	9	14	16	0	128	10·7

Corresponding number of ripe nuts harvested :—

1	0	0	0	1	2	0	1	0	0	2	0	7	0·6

1919 *Crop.*

Number of female flowers in each consecutive bunch :—

12	17	18	24	17	24	12	13	15	10	8	20	190	16

Corresponding number of ripe nuts harvested :—

1	0	1	0	1	2	1	0	1	0	1	0	8	0·67

1920 *Crop* (8 *months*).

Number of female flowers in each consecutive bunch :—

22	26	32	29	29	23	23	12	196	24·5

Corresponding number of ripe nuts harvested :—

1	2	1	2	2	2	3	1	14	1·75

TREE No. II, 134.—During the period covered by these records the tree produced a fresh leaf on an average of every twenty-nine days, and the stem made 3 feet 1 inch growth. Three leaf axils failed to produce an inflorescence bud. In one the inflorescence bud failed to develop, and in two the bud was destroyed by rhinoceros beetle. Seven inflorescences failed to produce female flowers. Only twelve bunches ripened fruit out of twenty-nine leaves produced, and of these twelve, ten ripened only one nut each. The root-bearing portion of the base consisted of the basal 1 foot 10½ inches. The first ½ foot carried 340 roots. The second ½ foot carried 725 roots. The third ½ foot 710 roots, and the apex carried 215 roots, making a total of 1,900 roots. This tree seems to have devoted much of its energy to the production of wood.

1918 *Crop.*

												Total	Average
Number of female flowers in each consecutive bunch :—	5	0	0	0	0	4	5	6	4	11	8	43	4
Corresponding number of ripe nuts harvested :—	1	0	0	0	0	1	0	1	0	2	4	9	0·8

1919 *Crop.*

Number of female flowers in each consecutive bunch :—	3	3	0	0	0	9	9	6	15	?	13	?	58	5·8
Corresponding number of ripe nuts harvested :—	1	1	0	0	0	1	1	0	1	1	0	1	7	0·5

1920 *Crop* (5 *months*).

Number of female flowers in each consecutive bunch	Killed by beetle or failed to develop.
Corresponding number of ripe nuts harvested	

The three regular bearing trees all show a better developed root system than the three irregular bearing trees, as far as this is indicated by the actual number of main roots given off from the stem base. There is, however, the important factor of root habit to be taken into consideration, and this could not be ascertained by merely counting the number of roots.

One point noticed in this examination was that there was hardly a dead root to be found of all those which had been produced during the life of each tree. This does not necessarily mean that all the roots on the tree were actively working. Many of them are practically dormant, but can take up active work when necessity arises for them to do so.

The following is the examination of the root system of an old tree about 60 to 70 years old. From this it will be seen that the roots of the tree commence to die from the apex upwards, and in many cases, when this stage has been reached, the tree, in order to maintain life, will commence to form new roots above the normal root-producing area. The tree was felled, and one quarter of the root-bearing portion of the base was exposed. The figures given are those actually counted multiplied by four.

The tree had evidently been planted deeply, as 1 foot 6 inches of the stem, which did not bear roots, was below ground level. The vertical depth of the root-bearing portion of the bole was divided into 5-inch sections. In the first there were 328 roots. In the second there were 552 roots. In the third there were 632 roots. In the fourth there were 236 living roots, and the scars of 712 roots which had died. In the fifth there were 88 living roots, and the scars of 692 roots which had died. The apex was quite dead, and showed the root scars of 380 roots which had died. This makes a total of 3,620 roots which the tree had produced during its life, of which 1,836 were still alive. Many of these living roots must have been nearly as old as the tree itself, since no root scars of dead roots were found in the first three sections (i.e., the upper 1 foot 3 inches of the root-bearing portion of the bole). The examination of the roots of trees about 20 years of age, which has already been given, shows that this upper portion of the root-bearing portion of the bole is amply supplied with roots at that age. It is thus evident that the roots of the coconut can and do live for a very long period.

In the case of this old tree where the base of the root-bearing portion of the bole had already died, the following is the colour analysis of the roots, the colour becoming darker as the root gets older :—

White roots	6·0 per cent.
Orange roots	7·8 ,,
Red roots	9·1 ,,
Brown roots	9·9 ,,
Dark brown roots	12·9 ,,
Dead roots	54·3 ,,

If the dead roots are disregarded, the figures are of interest in showing the effort made by the tree to counteract the gradual dying of the base of the bole by producing fresh roots. These figures are :—

White roots	13·2 per cent.
Orange roots	17·1 ,,
Red roots	20·0 ,,
Brown roots	21·6 ,,
Dark brown roots	28·1 ,,

This shows that at least 30 per cent. (white and orange) of the live roots are of quite recent origin.

The following is the colour analysis of the roots of a tree about twenty years old, which had produced during its life 2,485 roots from the bole :—

White roots (this year's growth) ...	1·8	per cent.
Orange roots	7·6	„
Red roots	16·4	„
Brown roots	31·8	„
Dark brown roots	41·0	„
Dead roots...	1·4	„

It has already been mentioned that an old tree which has commenced to fail will produce fresh roots above the normal root-producing area at the base of the stem. If the tree has been planted deeply and a portion of the stem above the root-producing area is buried, the tree will produce fresh roots from this part. It can, however, produce roots under favourable conditions high up on the stem, and in some countries advantage is taken of this to save the life of a particularly valuable tree. In some places the tree is brought to the ground by cutting the roots at one side and causing the tree to fall. The fallen stem is then buried in the ground and in time the crown bends up to the light and a new tree is formed. There is another way also by which an old tree is saved. A platform is built high up around the stem. Soil is then piled up around the tree on this and if this is kept moist a fresh root system is formed in this soil. The tree is then cut down below this new root system and the top is planted in the ground.

THE RANGE OF THE ROOT SYSTEM OF THE TREE.

This of course varies to a great extent with the texture and the natural drainage of the soil. In a sandy soil the roots will travel much further than in a heavy soil, and where the drainage is efficient the roots will go much deeper into

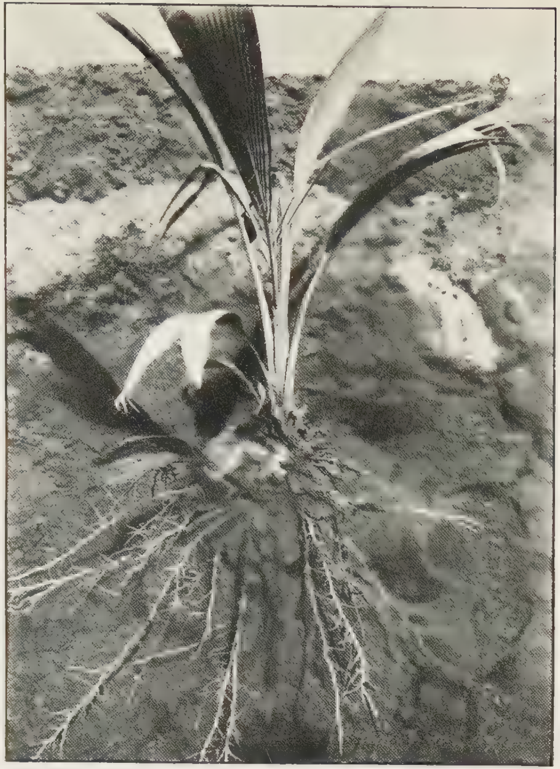


Fig. 1.

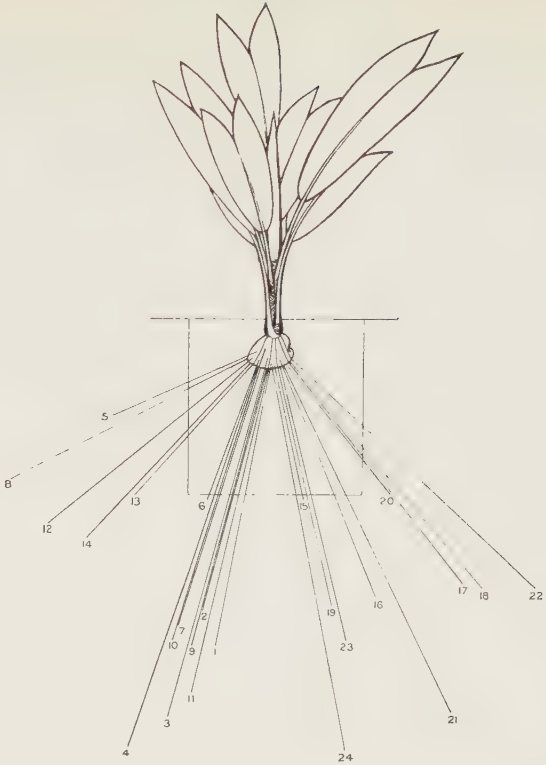


Fig. 2.

The root system of the young coconut nine months after planting out.
Fig. 1.—Photograph showing root habit. Fig. 2.—Diagram showing spread of each root (the square is the planting pit 1 yard cube).

the soil than where this is deficient. In any case the roots cannot go deeper than the permanent stagnant water table in the soil when this is at its maximum. The coconut root is unable to withstand stagnant water whether it be sweet or not.

The diagram on Plate I (fig. 1) represents the dissection of the root system of a coconut seedling made nine months after this had been transplanted out. The square represents the 3 foot cube planting hole which was filled up with soil mixed with fish guano and wood ashes. Each main root has been followed up, and the depth below ground level, as well as the lateral distance from the stem, has been noted. The seedling was planted with the top of the nut just below ground level, and at the time of examination this was 5 inches below ground level. A portion of this distance is due to the soil in the planting hole settling. The greatest lateral spread of the roots is 4 feet 6 inches, and the greatest vertical depth of the root system is 7 feet 5 inches. It will be noticed that every root has gone beyond the original cube of manured soil in the planting hole; also that there is a distinct downward tendency of these first-formed roots, which are evidently intended to serve the plant as a protection against drought. Fig. 2 on this plate is a photograph of the dissection of a similar seedling made at the same time, which shows the branching habit of these early-formed roots. The soil where this was grown is a red sandy loam of uniform texture to a depth of some 25 feet and with free drainage.

Plate II shows a diagram of the dissection of a three year old seedling tree planted at the same time as the preceding and under the same conditions. The dissection was done in July, 1920, two years after the seedling was transplanted. Fig. 1 represents the vertical spread and fig. 2 the lateral spread. A trench was dug 14 feet away from the stem of the tree along a circumference, and the position of each main root cap was noted as it was unearthed. Many of these proved to be the root ends of strong branch roots. Sixty-three main roots were given off by the tree, of which three had extended laterally more than 10 feet, inclusive of which fourteen had extended beyond 8 feet, thirty beyond 6 feet, fifty-two beyond 4 feet, fifty-six beyond 2 feet. Including the main branch roots seven roots ended within the 2 foot circumference, nine between the 2 and 4 foot circumference, thirty-three between the 4 and 6 foot circumference, twenty-nine between the 6 and 8 foot circumference, sixteen between the 8 and 10 foot circumference, and two within the 10 and 12 foot circumference. Regarding the depth growth of the roots one branch root had gone down over 8 feet, eleven main and four branch roots had gone down between 6 and 8 feet, five branch roots had gone down between 4 and 6 feet, and eleven main roots and eight branch roots had gone down to between 2 and 4 feet, and forty-one main roots and fifteen branch roots had gone down less than 2 feet.

It will be noticed that the roots which have gone down to greater depths correspond, in the main, to the root system shown in Plate I of a seedling nine months after planting, and it may be presumed that these are the earliest roots formed. Since their formation the plant seems to have devoted all its energies in making a more shallow root

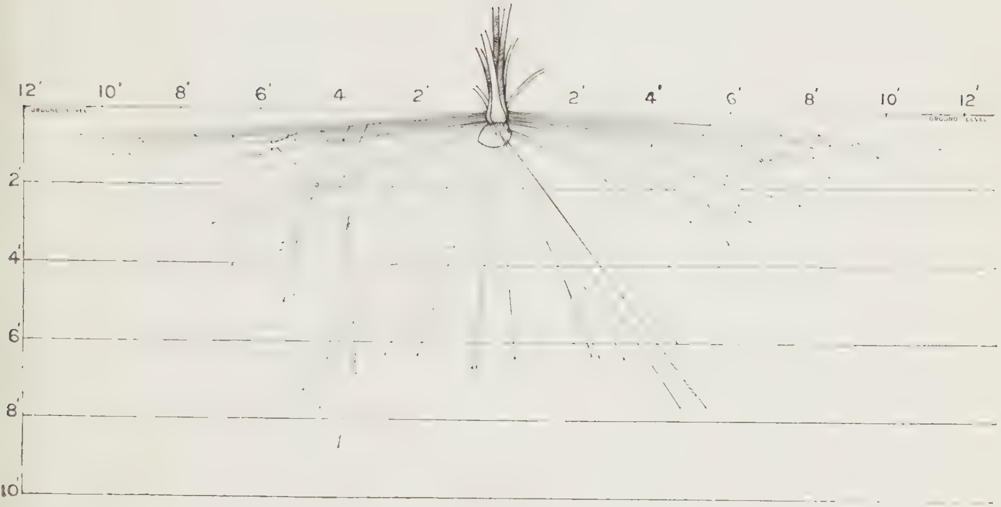


Fig. 1.

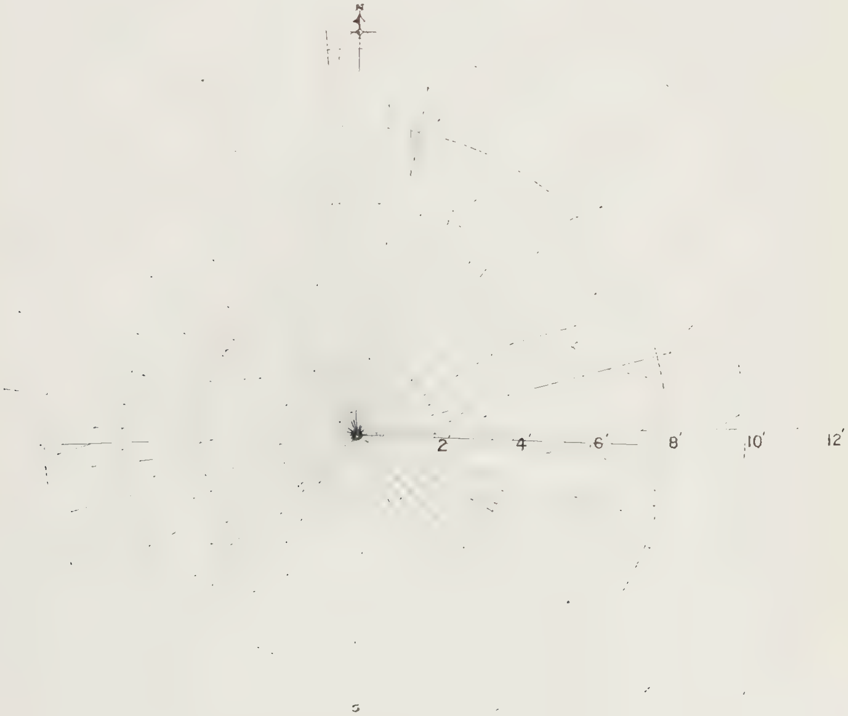


Fig. 2.

Plan of root system of a coconut tree two years after planting out

system in search of plant food. At the same time in order to protect itself against drought, many of these surface roots have sent out strong branches growing almost vertically into the soil. The surface "feeding roots" branch very freely, and it is on these that the plant is mainly dependent for the supply of food from the soil. (Fig. 2, Plate III, is a reproduction from a direct blue print photograph of a surface-feeding root.) The vertical roots are evidently "water roots," that is to say, the main object for their formation is to supply the tree with water. All the first roots formed are more or less of this type since at this stage of growth there is little need for the roots to make an effort to supply plant food from the soil, as there is a liberal supply of this both in the husk and in the meat of the seed nut. That from the husk is taken into the plant by fibrous roots which branch freely through this, and that from the meat is absorbed and elaborated by the haustorium, or as it is termed the "apple," which is formed in the hollow centre of the nut from the base of the seedling. These "water roots" form small branch roots (Plate IV, figs. 3 and 4) which greatly increase their capacity to absorb water from the soil and also increase the range from which they can absorb water. It is true that they must take in plant food constituents in solution as well and thus aid in nourishing the tree, but this in the case of a seedling tree is a minor consideration.

The later formed "water roots" appear to be almost entirely strong branch roots (Plate IV, fig. 4), given off from the surface "feeding roots," and, in countries where there is a recognized dry season, these play a most important part in maintaining the life of the tree; for in the dry weather if the soil becomes dry, the "feeding roots," which are almost all within the surface 3 feet of the soil, cease, to a great extent, to function and the tree is thus dependent on any reserves stored up within its tissues and on these "water roots."

Plate III, fig. 1 is the dissection of the root system of a grown tree some twenty to twenty-five years old and represents 22·5 degrees or one-sixteenth of the entire root system of the tree to a depth of 7 feet. Here the importance of these "water roots" is clearly evident. These are mainly strong branch roots which grow from the surface "feeding roots" almost vertically into the soil. In this dissection a wall of earth was left at 5 feet intervals (shown by dotted lines in the figure) in order to keep the main roots in position when the intervening soil was washed out, and hence the whole of the root system is not visible. The base of these intervening walls covered practically the same area as the part washed out, and hence it may be presumed that the number of "water roots" would be about double the number shown in the plate. Except in the section nearest the bole almost all these "water roots" are strong branch roots. In the first section, i.e., that nearest the bole, the number of main and branch roots which go into the floor below 7 feet was 23; in the second section the number was 37; in the third 36; in the fourth 28 and none in the fifth. The total number in the whole sector is 124. Presumably, therefore, there will actually be about double this number if those in the portion not washed out are

Fig. 1.

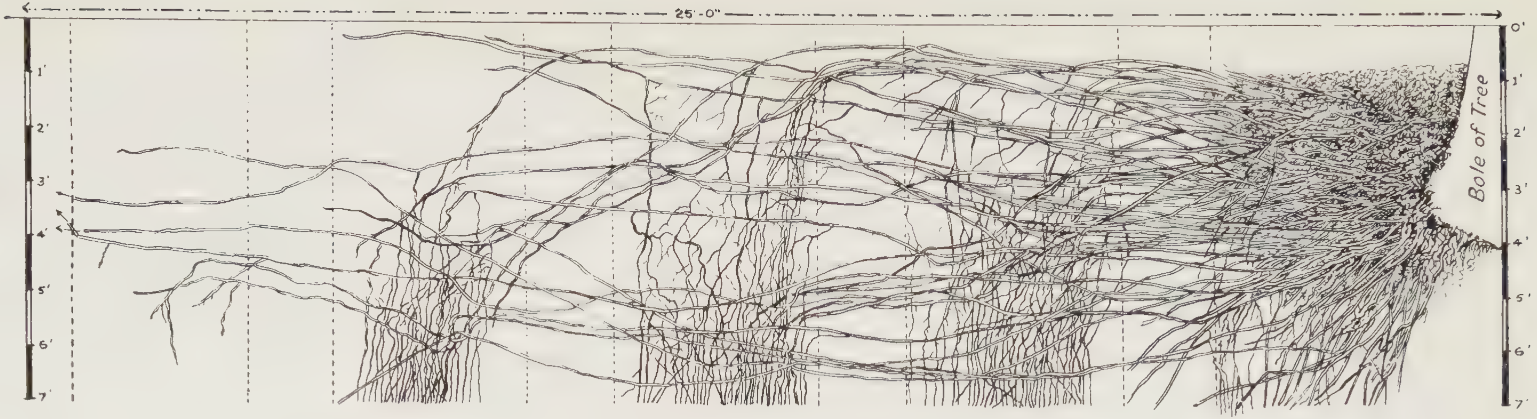


Fig. 2.

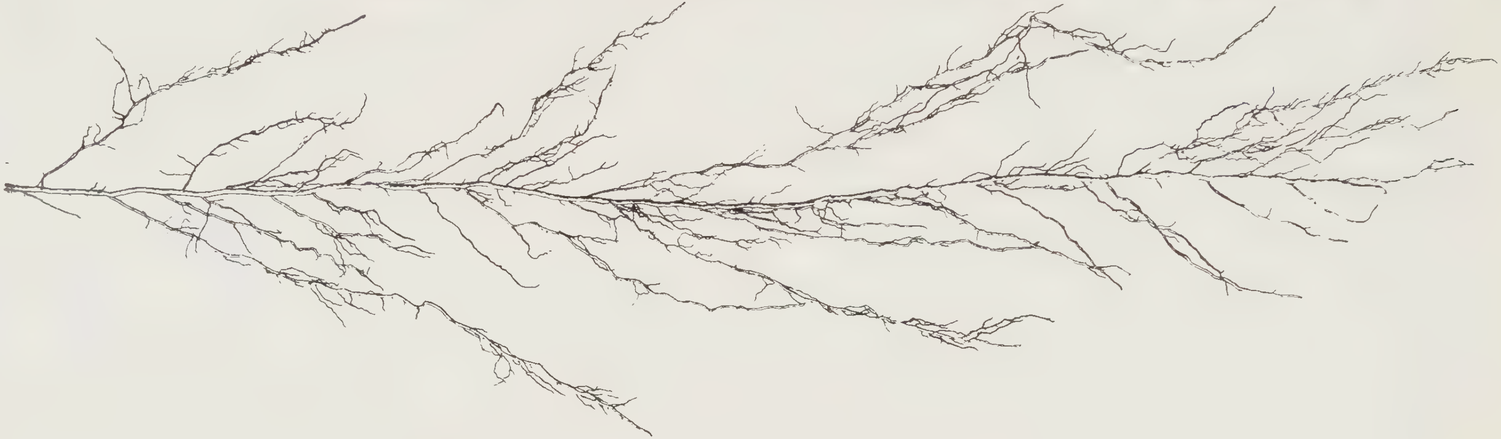


Fig. 1.—The root system of a grown tree.
Fig. 2.—A surface "feeding" root.

included. This represents one-sixteenth of the entire root system of the tree, therefore there will be some 4,000 of these "water roots" going down to at least a depth of 7 feet. The total number of main roots given off from the base of this particular tree was between 1,300 and 1,400, of which 1,268 reached the dividing wall between the first and the second sections; 968 emerged into the second section, of which 688 reached the dividing wall between the second and the third sections; 672 emerged into the third section, of which 560 reached the dividing wall between the third and the fourth sections; 378 emerged into the fourth section, of which 176 reached the dividing wall between the fourth and the fifth sections; 112 emerged into the fifth section and of these only 48 reached the wall of the fifth section. These figures have been arrived at by multiplying the actual number counted in the segment washed out by 16.

This gives some idea of the important part which the "water roots" play in supplying the tree with water and to a certain extent with plant food. It also demonstrates very clearly the necessity for free water movement through the soil, which is what good drainage implies. It further gives a very good idea of the lateral spread of the main roots of the tree, though there is evidence that many of these lateral roots travel to a much greater distance than the 25 feet shown in this dissection.

Where drainage is deficient these "water roots" are unable to go down in this way in search of water, and this explains why it is that where coconuts are grown on soils with a high water table without water movement through the soil, a spell of dry weather of even a few weeks' duration is so much feared. Under such conditions, though these "water roots" are sent down by the plant, they die at the ends as soon as they reach stagnant water and are therefore of no use to the plant.

One point noted in making this dissection was that very few of these main roots were actually growing in length. Many of these were practically dormant, especially those which only reach the first and second sections. They had neither a growing root end or root cap, nor had they formed branch roots of any importance. Many, however which had no root cap to the main root, had sent out strong branch roots, either "water roots" or surface branching "feeding roots." Most of the roots within the surface 2 feet and many of those to a depth of 3 feet had sent out branch "feeding roots," which, in their turn, had sent out innumerable branchlets. Plate XXXVI gives a good idea of the appearance of such branchlets when the surface soil has been removed, and it can be seen how these take complete possession of the soil.

An interesting feature in the formation of these branching rootlets is the seeming regularity with which they are formed. This is especially evident in a free loose soil. Here the root, whether a main or branch root, does not grow straight, but in the form of a flattened spiral or zigzag. At each outward bend of this root a branch root emerges through the cylindrical shell of the root and produces the seemingly regular branching figured in Plate IV, fig. 1.

PLATE IV.

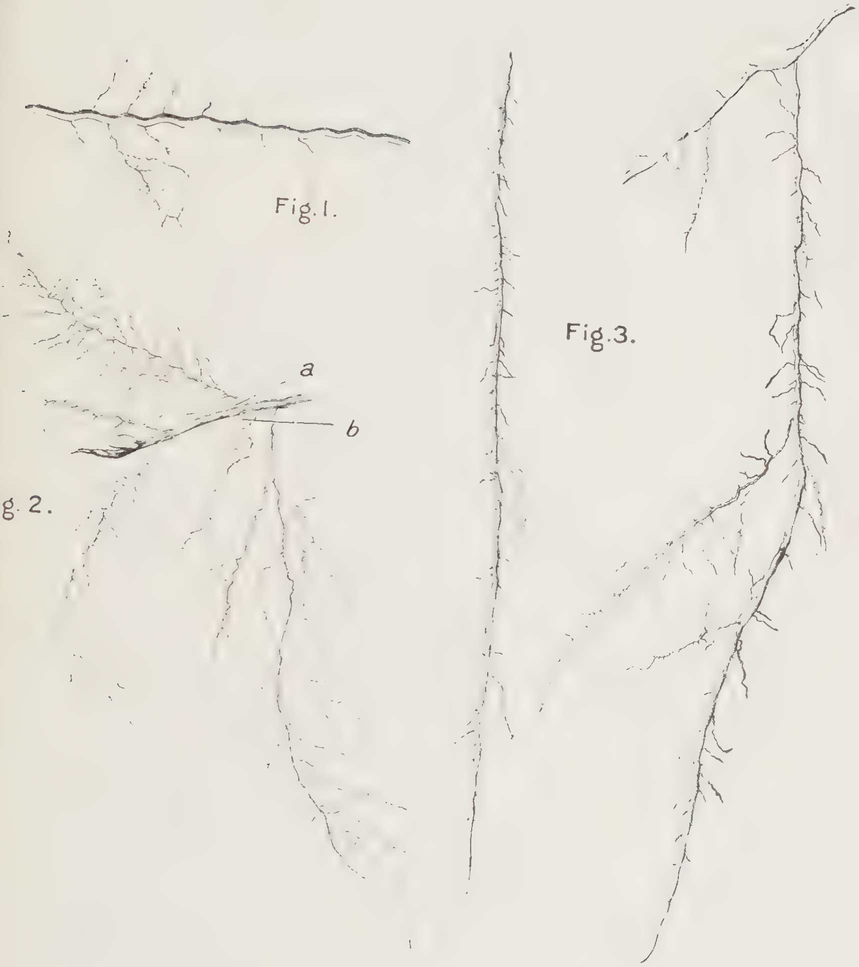


Fig. 1.
a
b
Fig. 2.
Fig. 3.
Fig. 4.

Roots of the coconut palm.

Fig. 2.—(*a*) Dormant or breathing (?) root; (*b*) dormant or breathing (?) root changing into a feeding root.

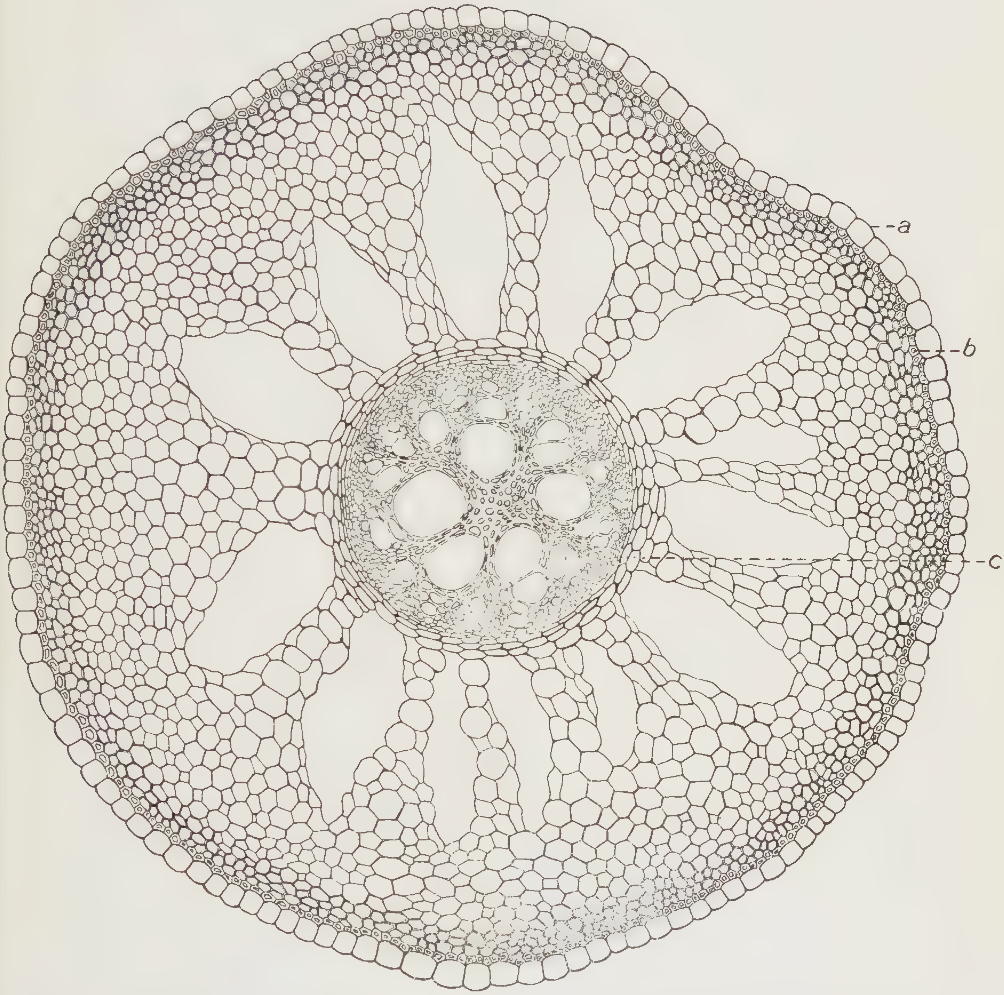
Many more branch roots are formed than are actually employed in the normal function of roots in absorbing plant food. These are apparently dormant and can be seen as small rough protuberances on the surface of the main roots. By some it is thought that these are breathing roots, and certainly they can take on this function if the roots are kept in water. They do, however, grow into normal feeding roots when occasion or necessity arises, as figured in Plate IV, fig. 2. These undeveloped roots are surrounded by corky cells at the place where they emerge from the main root, and it is possible that this is the normal method of emergence, since these corky cells hermetically seal the wound caused by the root forcing its way through the outer shell of the main root.

In all coconut roots there appear to be the hyphæ of a symbiotic fungus and these are specially concentrated in these dormant roots. What their use is to the coconut has not yet been studied. It may be that they assist in the absorption or assimilation of nitrogen which is needed in large quantities by a bearing tree for the formation and maturing of its fruit.

The main roots can be easily damaged by lateral pressure as can be seen when the structure of the root is discussed. They are also very liable to be killed during dry hot weather when they have grown too near the surface. So also when they have grown too deep and there is a rise in the stagnant water level in the soil. The root when so damaged seems to be able, when favourable conditions again arise, to repair this damage by what appears to be the formation of a new root cap behind the place of injury. This is probably only the development of an extra strong branch root. This is depicted in Plate IV, fig. 2, which shows not only the formation of such a new root cap, but also how the root has maintained its vigour during a period of drought by sending down a strong root deeper into the soil in search of water.

THE STRUCTURE OF THE ROOT.

Plate V shows the cross section of a coconut root as seen through the microscope. This section has been made a short distance behind the growing point or root cap. It will be seen that it is fairly typical of the roots of other plants of the monocotyledonous group. The coconut root is not, however, furnished with root hairs, which are elongated cells growing out from the outside layer of cells or epidermis. It is through these root hairs that most plants take in water and plant food from the soil. The coconut is furnished with an epidermis but none of the cells protrude. The absorptive surface is thus very much restricted, which makes it necessary that the roots should branch very freely. This epidermis is only present on the very tender root immediately behind the root cap, and as the root becomes older it disappears. Underneath the epidermis are several layers of small long sclerenchyma cells, which in the very young root are thin walled, but as the root gets older the cell wall thickens until the cell cavity almost disappears. The process of thickening can be seen to have commenced in the plate. As they thicken, these cell walls change in colour. First to an orange and later on to a brick red, until finally they become so dark that they appear nearly



Transverse section of the root of the coconut palm (magnified). (*a*) epidermis; (*b*) cells with thickened walls; (*c*) pericycle.

black. It is these cells which give the root its typical colouring. These cells are of considerable length, and the cell walls become quite hard and are impervious to water. They thus form an excellent protection for the vital part of the root within, which, if this outer covering is damaged so as to let in water, very soon dies. This provision is necessary in the case of the coconut as, unlike trees of the dicotyledonous group, the roots are incapable of healing a wound. They have no growing tissue near the surface with which to heal an injury. These long thick walled cells greatly increase the tensile strength of the root.

Within this ring of hard thick walled cells are large thin walled cells which enclose large air spaces. These form an elastic cushion between the outer rind and the central vascular system.

Within this again there are two or three layers of smaller flattened-looking cells, and the innermost ring of these forms what is called the pericycle. It is from this pericycle that new branch roots are formed. This pericycle encloses the vascular system by which sap is carried to and from the stem. Here also there are large air cavities, known as vessels, and in the centre there are again found thick-walled woody cells.

The root, therefore, is constructed in the form of a more or less hollow cylinder, in the centre of which is supported a solid core. It is able to withstand a considerable pulling strain, though it is very easily damaged by lateral pressure.

There is no difference in the structure of the main and branch roots.

It has been mentioned that the branch rootlets of the coconut are short lived and, as these are entirely surface roots, a system of root pruning is in some countries practised. Both in Ceylon and South India careful growers always cultivate their gardens. This destroys large numbers of these surface rootlets and encourages the plant to replace these by fresh ones. In fact so strong is the belief in South India that these roots should be destroyed in this way that the people believe that they are of no use to the tree ; and surface cultivation, either with hand implements or with the plough is done regularly at the close of the rainy season and again just as the rains of the monsoon commence.

The only economic use made of the root of the coconut, and that only in the country where it is grown, is for medicinal purposes, as an astringent.

THE STEM.

The stem of the coconut, when once formed, does not materially alter in thickness. It may become slightly less in circumference as the tree gets older and the outer covering of the stem dries, but beyond this the thickness of the stem at any particular place is determined by the vigour of the tree at the time it is formed.

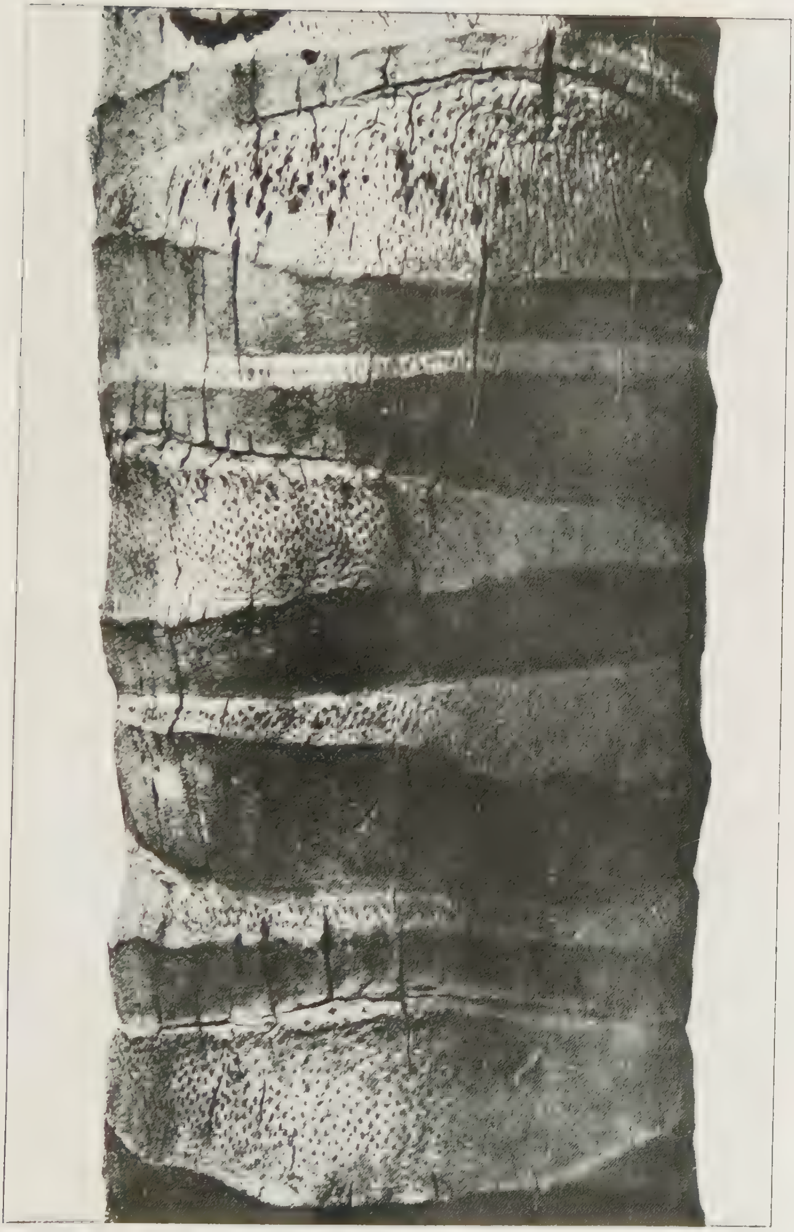
The stem of the tree has no special and definite area by which the sap ascends and descends. The whole stem remains alive and active throughout the life of the tree. It thus differs from a tree of the dicotyledonous group, which has between the bark and the wood a layer of living and growing cells which form wood on the inside by which sap ascends, and bark on the outside by which sap descends. There is therefore no "heart wood" which is inactive, and there is no dry or dead bark. The whole stem of the coconut is alive and active, but it contains no growing tissue. If the stem is damaged, it is unable to repair the damage. The wound may dry up, but no new tissue will be formed to heal over the wound. But since the whole stem of the coconut remains alive, it can withstand a considerable amount of damage and the tree can still continue to grow.

Another difference between the stem of the coconut and that of an ordinary tree is that it is incapable of forming leaf-bearing branches. In the case of a dicotyledonous tree, if the crown is damaged, it is able to repair this either by developing a dormant bud or by forming a new bud from the growing tissue between the bark and the wood.

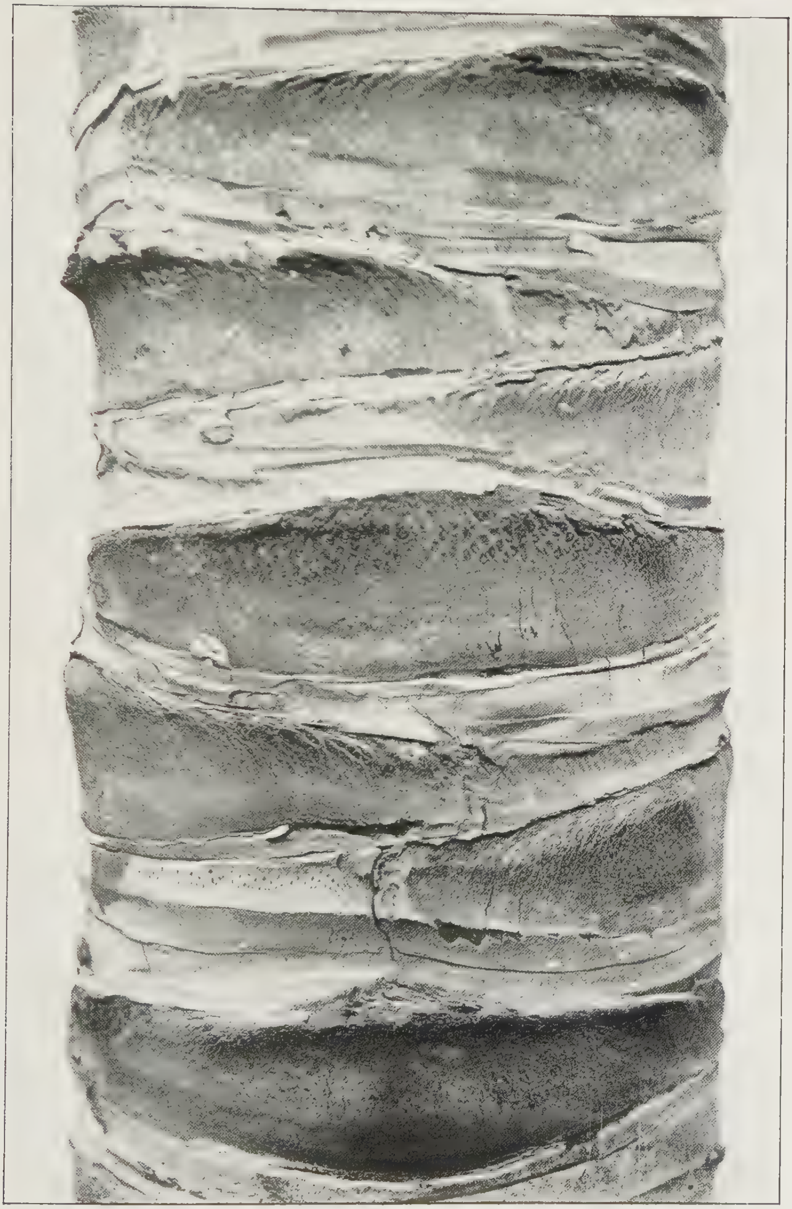
In the dicotyledonous tree a bud is formed in the angle of each leaf. This may develop at once or it may lie dormant till it is required by the plant. This is not the case with the coconut. Here there is only one vegetative bud ever formed on the tree. It is true that each leaf on a coconut, at any rate a tree that has commenced to form fruit, does develop a bud in its axil, but this is invariably a flowering bud, and, if it does develop, it will produce a flowering branch. If this flowering bud does not develop then it dies. It does not lie dormant as in the case of the dicotyledonous tree.

The coconut then is dependent on a single vegetative bud for its existence. If this dies the whole tree dies. This bud is situated at the apex of the stem and is commonly called the "cabbage."

Plate VI is from a photograph of the stem of a tree taken at a place where the leaf scars on the stem show that the tree had just commenced to flower at that stage in the development of the tree. The plate shows the scars of six leaves, and between each scar there is a smooth, well defined interspace. The middle of the sixth or uppermost scar is, within 10 degrees, immediately above that of the bottom or first scar. At the upper edge of the widest part of the scar, there is to be seen evidence of the scar of the flowering branch, which is attached both to the leaf as well as to the stem. This, however, is not very clearly defined, and it is



Stem of the coconut palm, lower part, showing leaf scars when this was coming into bearing.



Stem of the coconut palm, showing leaf scars on the bearing portion of the stem.

probable that these first formed flowering branches failed to develop fruit.

Plate VII is from a photograph of the stem of a tree taken at a place where the leaf scars on the stem show that the tree was in full bearing. There are the scars of eleven leaves in this plate. The scar of the sixth leaf is, within 10 degrees, immediately above the first, and similarly the scar of the eleventh leaf is within 10 degrees of being immediately above the sixth. The interspaces between one leaf and the next are hardly discernible so close is one leaf scar to the next. At the upper edge of the widest part of the leaf scar, the scar of the fruiting branch is clearly to be seen. The outline of the ninth scar from the bottom in this plate is seen to be concave, showing that the fruiting branch in that leaf axil had carried a heavy bunch of nuts. The pits on the leaf scars are the scars of the vascular bundles through which the sap flowed to and from the leaf. These are seen to be much further apart where the scar is widest.

It can be seen from these plates that much valuable information can be gathered from a close observation of the stem. When a leaf falls it leaves a rough pitted scar on the trunk of the tree, which encircles the whole stem. If the tree has made vigorous growth there is a well marked interspace between one leaf scar and the next, which is quite smooth. If the growth has been stunted, this interspace is small. It is also possible to see when a tree first commenced to flower, as the fruiting branch, which is attached both to the leaf and the stem, leaves a scar at the top of the widest portion of the leaf scar. When a tree is once in full bearing the leaves of the tree are much closer together, as the energy of the tree is mainly devoted to the formation of fruit rather than of wood. The leaf scars are also much deeper, because the leaf stalk has to bear the full weight of the fruit bunch and thus presses much more heavily on the still tender stem. It is possible, therefore, to gauge with very fair accuracy, not only when a tree commenced to bear, but also whether a tree is a good and regular cropper; because a succession of good bunches will be shown by a corresponding succession of deep leaf scars on the stem.

If the stem of a coconut tree be split, it will be found to consist of a large number of stout strands embedded in a matrix of soft tissue. These strands do not run parallel with the tree trunk, but from one side to the other. This explains why it is that a tree can thrive even after the stem has received serious injury. These strands are much closer together towards the outside than towards the centre, and this quasi-tubular structure gives the stem the power of withstanding a considerable lateral strain, which it often has to experience when the wind is severe.

The stem of the coconut grows erect under normal conditions of cultivation. Trees on the margin of a plantation will often lean outwards towards the light, and when there are prevailing winds from one direction, the tree will lean towards the wind. Occasionally, and in old trees especially, the stem will develop a spiral growth.

The wood of the young tree, as well as that in the centre of the old tree, is valueless as timber, but the lower part of the stem of an old tree will furnish quite a useful timber.

This is used mainly for rafters and for building, and is occasionally used for making furniture. When the tree is felled, the outer rind is removed, then the stem is split and the soft tissue in the centre is removed. The usual method of seasoning the timber is to soak it in salt water for at least three weeks to a month, after which it can be used.

THE CROWN.

Since the coconut has no branches, the leaves have to take the place of these. The number of these on any one tree will vary from time to time; and the number on one tree will vary from the number on another tree at the same time.

The former variation is dependent on several causes, all of which appear to be dependent on an adequate supply of plant food. Where there is a definite rainy season the rate of leaf development slows down during that time. This is a question of the supply of plant food. The coconut tree is a strong light-demanding tree, and must have abundant sunshine if the regular and full supply of sap from the roots to the stem is to be maintained. During the cloudy weather of the rains, the rate of leaf development is considerably reduced. This has been calculated in the following table, the rate being calculated by the number of flowering branches which flower during periods of two months. Since each leaf normally produces a flowering branch in its axis, this represents the rate of leaf development. The figures are the average of thirty regularly bearing trees, and have been taken from the cropping registers maintained on the Government Coconut Station on the Malabar coast of India. The figures of the average rainfall of the locality have been placed beneath the figures, showing the rate at which flowering branches develop, and it will be seen that during the period of four months, when the rains are heavy, the rate of leaf development is at its lowest :—

Period:	Dec.-Jan.	Feb.-Mar.	April-May	June-July	Aug.-Sep.	Oct.-Nov.
Number of flowering branches which flowered	2·1	2·6	2·9	1·7	2·0	2·7
Rainfall during the period in inches	0·77	0·14	8·80	76·64	30·78	9·72

The seasonal factor also influences the length of the life of the individual leaf. During the rainy season very many more leaves fall from the tree than is the case in the dry weather. This is, however, to a great extent due to the moist atmospheric condition favouring the growth of fungus—*Pestalozzia palmarum* is always seen on the older leaves of the coconut, and during the rainy season its increased vigour causes the more rapid decay of the leaf, while saprophytic fungi aid in destroying the attachment of the leaf and the stem.

The rate of leaf development is often temporarily expedited by the fact that the flowering bud in the leaf axil fails to develop, or, if it does develop, fails to set any fruit. Any rapidly growing part of the coconut tree makes heavy demands on the supply of plant food within the plant. This is especially the case with the young growing fruit, as well as with the tender leaves. Thus a cessation in the formation and development of young fruit for some time will enable the plant to form fresh leaves at a more accelerated rate. The converse of this is also true. Where there are a large number of young nuts swelling, the rate of leaf production slows down.

If a tree is not thriving the rate of leaf production is not only lessened, but the leaves do not last for the same length of time as on a vigorous tree.

Besides this variation due to external causes, there is the natural variation in the rate of leaf production inherent in the tree, which in its turn is probably dependent on a well-developed root system. In regularly bearing trees the average number of leaves formed in a year is about fourteen, and a variation has been noted of from twelve to nineteen in the same year on different trees.

In a regular bearing tree the number of leaves on the tree will usually range from thirty to thirty-five. Of these some fourteen will be carrying fruit branches in their axils, some ten of them will be younger than this, but will have fully expanded, and the remaining, some six to eight, will persist after the fruit from the bunches produced in their axils has been harvested. The majority of the last, however, will be past their prime and are of little value to the tree in assisting to elaborate sap. In less vigorous trees where the number of leaves is only some fifteen to twenty it will be found that the leaves are much shorter lived, and occasionally in such cases the fruits ripen after the leaf, in whose axis the bunch was produced, has fallen.

A tree with a compact crown and a large number of leaves will invariably be found to be a regular and heavy cropper. The compactness of the crown is due, as has already been explained in the previous chapter, to the short internode due to the energies of the plant being devoted to the production of fruit rather than to the formation of wood.

The general outline of the crown of a young tree is an oval; this is because there is a considerable internode or space on the stem between the formation of one leaf and the next. In the case of a vigorously growing young tree the length of that portion of the stem which carries the leaves will be more than 6 feet. As the tree comes into regular bearing the portion of the stem which carries the leaves gradually lessens till the outline of the crown is practically round.

In a bearing tree, each leaf normally produces a fruit bud in its axil. This does not necessarily mean that every leaf represents a bunch. Sometimes this bud does not develop. Sometimes it has been destroyed by the rhinoceros beetle before it has a chance of developing. Sometimes it only produces male flowers, and sometimes it produces female flowers, but these fail to set. There is no doubt, however, that some, if not all, of these deficiencies will yield to better treatment of the plantation; and, in order to be able to watch this, a knowledge of the leaf arrangement is essential. This knowledge is also of great importance if careful seed selection is to be made when collecting seed for sowing nurseries for planting up fresh areas.

Since the leaves of the coconut have to take the place of branches, Nature has provided that each leaf is so arranged that it receives the maximum amount of light. The dicotyledonous tree sends its branches in any direction where the leaf canopy has been broken, and thus repairs any damage done to the crown. The coconut can only repair such damage by the formation in the course of time of new leaves to take the place of those that have died and fallen.

The leaf arrangement is what is known as a two-fifths phyllotaxis. This means that each new leaf that is formed is given off at an angle of about 142 degrees round the stem from the previous one. Thus the sixth leaf is $142 \times 5 = 710$ degrees, or except for 10 degrees, twice round the stem. Thus the sixth leaf is within 10 degrees of being over the first, and the eleventh is similarly over the sixth. The same is the case with the second, third, fourth and fifth leaf. Thus there are five definite spirals of leaves. These spirals are to the left or the right according to the direction of growth, which varies in different trees. If the spiral is to the left, the growth is to the right, and vice versa. With this information it is easy to estimate what progress a tree is making. By counting up the spiral and multiplying by five, an estimate of the number of leaves on the tree can very rapidly be made. It is a simple matter to see if every leaf has formed a bunch, and it is also easy to estimate the age of any nut on the tree. Since the nut takes, on an average, a full year to ripen from the time the flowering branch opens, 365 divided by the number of bunches on the tree will give the rate at which a fresh bunch is formed. Thus if there are three bunches in each spiral the seventh bunch from the last opened flower will be $\frac{365 \times 7}{15} = 170$ days old. It is thus possible to estimate the effect of any particular treatment which has been given to the tree or plantation. Of course this information will not be available for some considerable time after the treatment has been started, since the female flowers have been laid down in the flower bud several months before the latter bursts. The points to be noted in examining a tree are: the regularity with which the bunches develop, the number of female flowers formed, and the number and proportion of female flowers which set. Such periodical and systematic examination of representative trees in a plantation will enable the grower to form an accurate estimate of its condition. It will also enable him to estimate what his crop is going to be with considerable accuracy. The arrangement of the leaves can clearly be seen by examining the leaf scars on the stem in Plate VII.

The centre of the crown is the most vital part of the tree. This is the "cabbage," and is the one and only vegetative bud which the tree ever produces. If this dies, the whole tree must die too. Hence Nature has protected this very thoroughly. Attached to each side of the base of the leaf stalk are what are termed stipules. These are seen more or less complete on the green and active leaves, but as the leaf dies these also commence to decay and disintegrate. These stipules have the appearance of coarsely woven fibrous cloth, but when seen thus they are dead and their function has largely ceased. They are, however, of the utmost importance to the young and erect leaves of the crown. When seen here they form a complete bandage which binds the leaf stalks of the young leaves around the more tender growth within. The base of these young leaves is still quite tender and very brittle, and were it not for this fibrous structure the whole of the top of the crown would break off. When young, these stipules are indistinguishable from the base of the leaf stalk and entirely surround the younger leaf within. As the leaf gets older, strong interwoven fibres are formed from the vascular bundles of this tissue, which are so strong that the stipules are able to support the centre of the crown even in the strongest winds. In a cyclone, it is not uncommon for trees to be blown down; they may be up-rooted, they may snap across the stem and the leaves may be torn off, but unless the crown has been damaged by beetle attack, it is very seldom that the shoot breaks.

The development of new leaves in the bud is very rapid. Apart from the leaves, which have already protruded from the crown, the number which have already been formed in the "cabbage" are not many. In the case of a tree where the crown was dissected out, there were only thirteen leaves formed in the "cabbage," which had not yet protruded and which could be distinguished without the aid of a microscope.

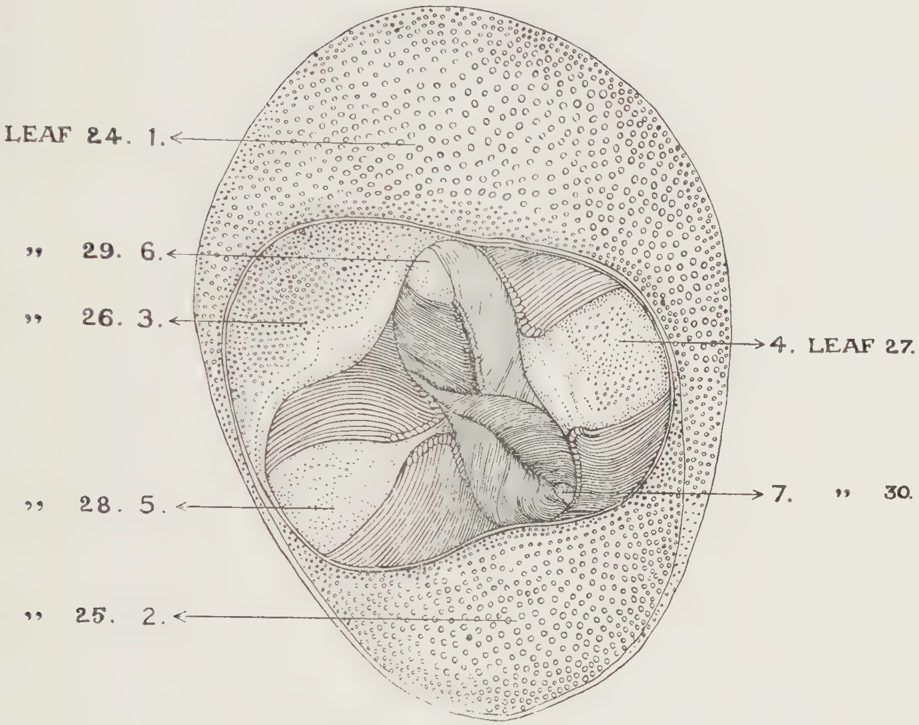
Plate VIII represents a cross section through the bud or "cabbage." This not only illustrates the leaf arrangement, but shows how the young leaves are packed away in the bud. The numbers refer to the order in which the leaves have been formed counting from the oldest leaf on the tree. It is interesting to see how rapidly these young leaves grow. Taking the rate of leaf growth at one leaf every twenty-seven days the following record of the sizes of the different leaves in this particular tree are of interest:—

Leaf No. 20 was the last fully opened leaf.

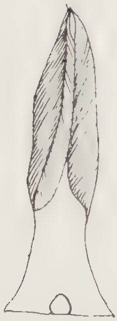
Leaf No. 21 was partly opened.

Leaf No. 22 was also partly opened though the leaf stalk was still growing. The leaf stalk was 37 inches in length.

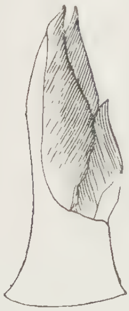
Leaf No. 23. The tip of the leaf was green but the leaflets had not yet expanded. Leaf stalk 9 inches long.



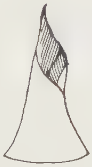
CROSS SECTION THROUGH BUD SHOWING LEAF ARRANGEMENT.



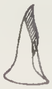
LEAF 30. Showing Spathe in axil of leaf.



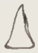
30-31.



32-33.



34-35.



36-37.

Leaf No. 24 (the oldest leaf shown in the section). The tip of the leaf was green but the leaflets had not yet expanded. The leaf stalk was 3 inches long.

Leaf No. 25. Leaf unopened. Leaflets slightly green at the tip. Total length of the leaf 7½ feet.

Leaf No. 26. Leaf quite white. Total length 5 feet 2 inches.

Leaf No 27. Total length 3½ feet.

Leaf No. 28. Total length 1 foot.

Leaf No. 29. The leaflets were a mere thread. Total length 9 inches.

The remaining leaves in the centre of the bud, viz., Nos. 30 to 37, are shown at the foot of the plate.

The section through the three leaves Nos. 24 to 26 is through the peteole or leaf stalk, and it can be clearly seen that this in each case encircles the younger leaf within. The section through the four inner leaves Nos. 27 to 30 is through the mid-rib and leaflets in each case. The whole of that part of the bud which is shown in this section was quite tender and brittle, and since some of the leaves were quite large and heavy it shows what very great strength there must be in the stipules to support this weight of growing tissue.

The "cabbage" is the most rapidly growing part of the tree. It is quite soft and brittle and has a sweet nutty flavour. It is also very rich in phosphates and potash. It is considered a great delicacy, not only by human beings, but also by the rhinoceros beetle, which burrows through the protective coverings into this soft tissue. It is very rarely, however, that the beetle reaches the vital part of the bud, but the passage which it makes may let in the "bud rot" disease and also the much dreaded red coconut weevil. In order to deal with the rhinoceros beetle it is of little use looking for damage from the ground. The damaged leaves which are visible from the ground have all been cut before the leaves were developed, and the beetle has left the tree several weeks or even months before.

THE LEAF.

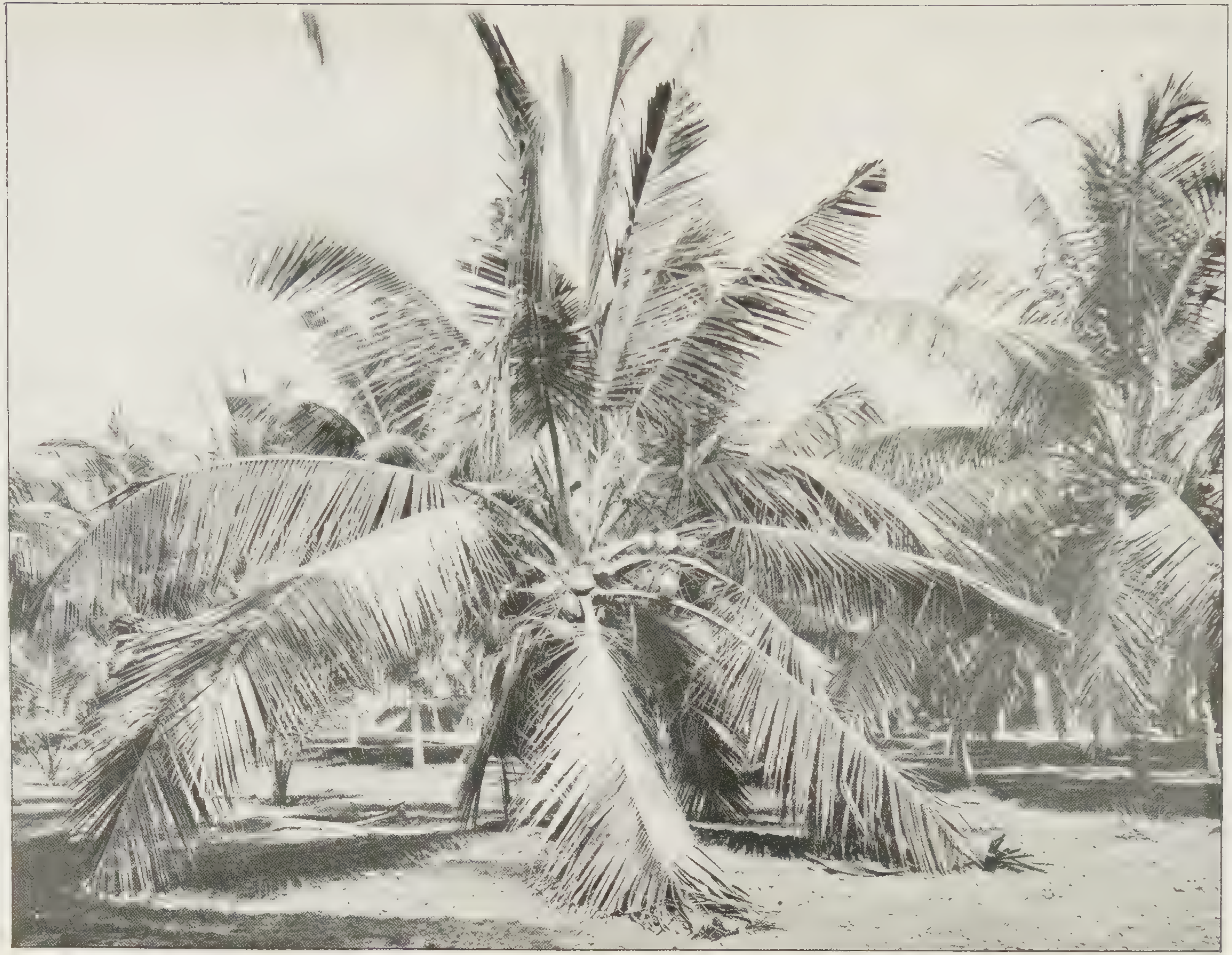
Since the leaves of the coconut tree have to take the place of branches and since the tree has at the same time to produce fruit continuously, the leaves are of great size in order to cope with this work.

The leaf is the laboratory of the tree, and it is in the leaf that the crude sap, which is taken in by the roots, is elaborated ; after which it is taken to whatever part of the tree it is required. The elaboration of sap consists in the formation of carbo-hydrates. This process can only go on in the presence of strong sunlight, and hence the necessity for the tree to expand as large an area of leaf surface to the sunlight as possible.

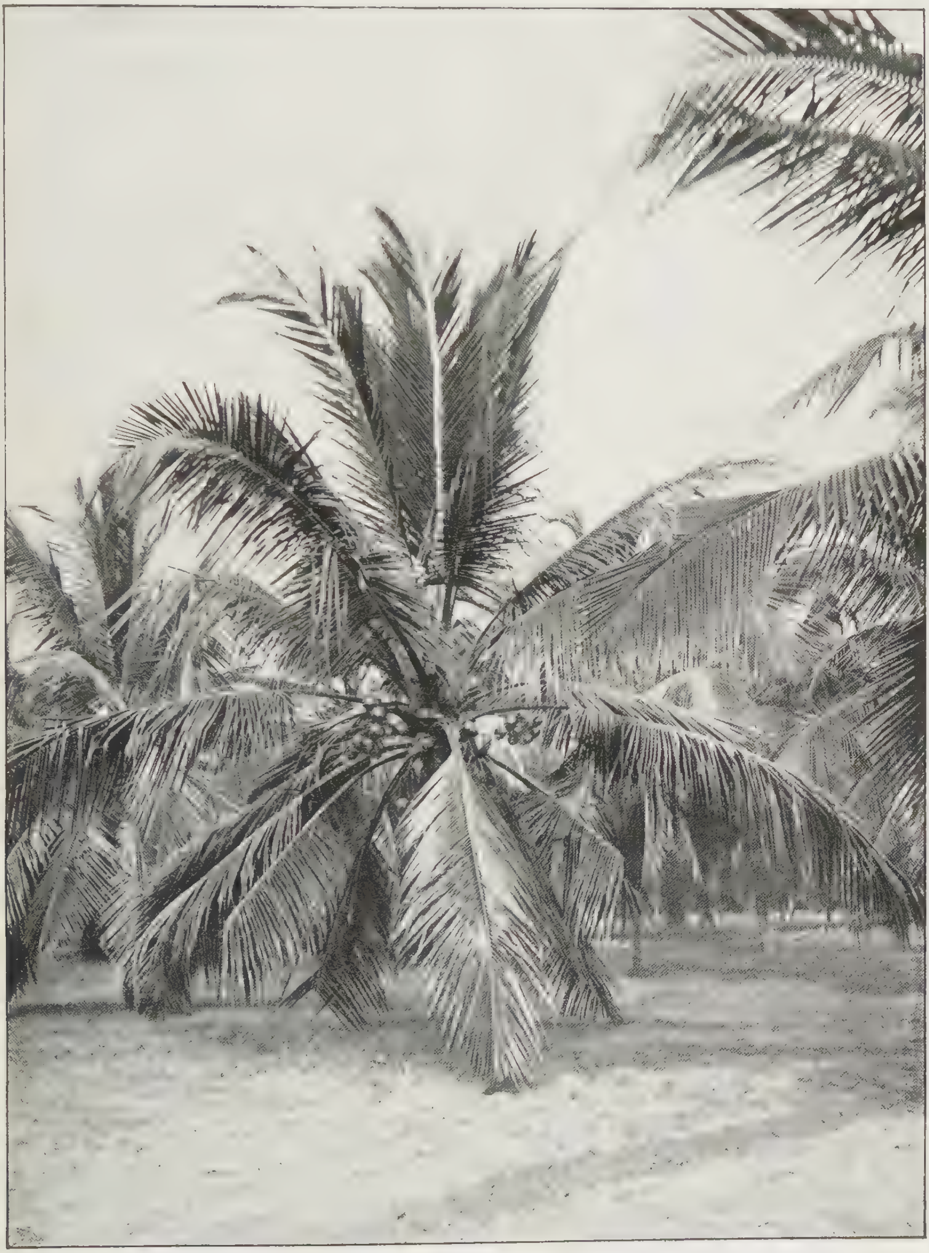
The leaf consists of the leaf stalk or petiole, the mid-rib or rachis and the leaflets. The leaf stalk not only attaches the leaf to the stem, but forms a bracket which has to support the weight of the bunch. As a bunch of nuts may weigh anything from 30 to 50 pounds when green, and as the leaf itself will weigh about 20 to 25 pounds, and has at the same time to be able to withstand a considerable strain from the wind, it can readily be understood that not only must the leaf stalk be very strong but that its attachment to the stem must be very firm. The base of the leaf stalk, therefore, is made to widen out so that the attachment is nearly half way round the stem of the tree. The strongest parts of the attachment are the wings on each side. Here the vascular strands are much closer together. The centre of the attachment is not so strong, for, if the join at the wings is cut, it is quite easy to tear away the leaf from the stem which is still quite tender where protected by the thick butt of the leaf bracket. This however cannot be done without injury, as the fibrous vascular strands which attach the leaf to the stem will tear the rind of the stem below the place of leaf attachment.

When young, the stipules form a part of the leaf stalk and surround the whole stem. So much are these a part of the leaf stalk that the leaf scar goes the whole way round the trunk of the tree (Plate VI). In young trees, these stipules frequently persist unbroken till the leaf dies. In bearing trees, however, the stalk of the fruit branch and the weight of the bunch so enlarge the angle between the leaf and the stem that the cincture is broken.

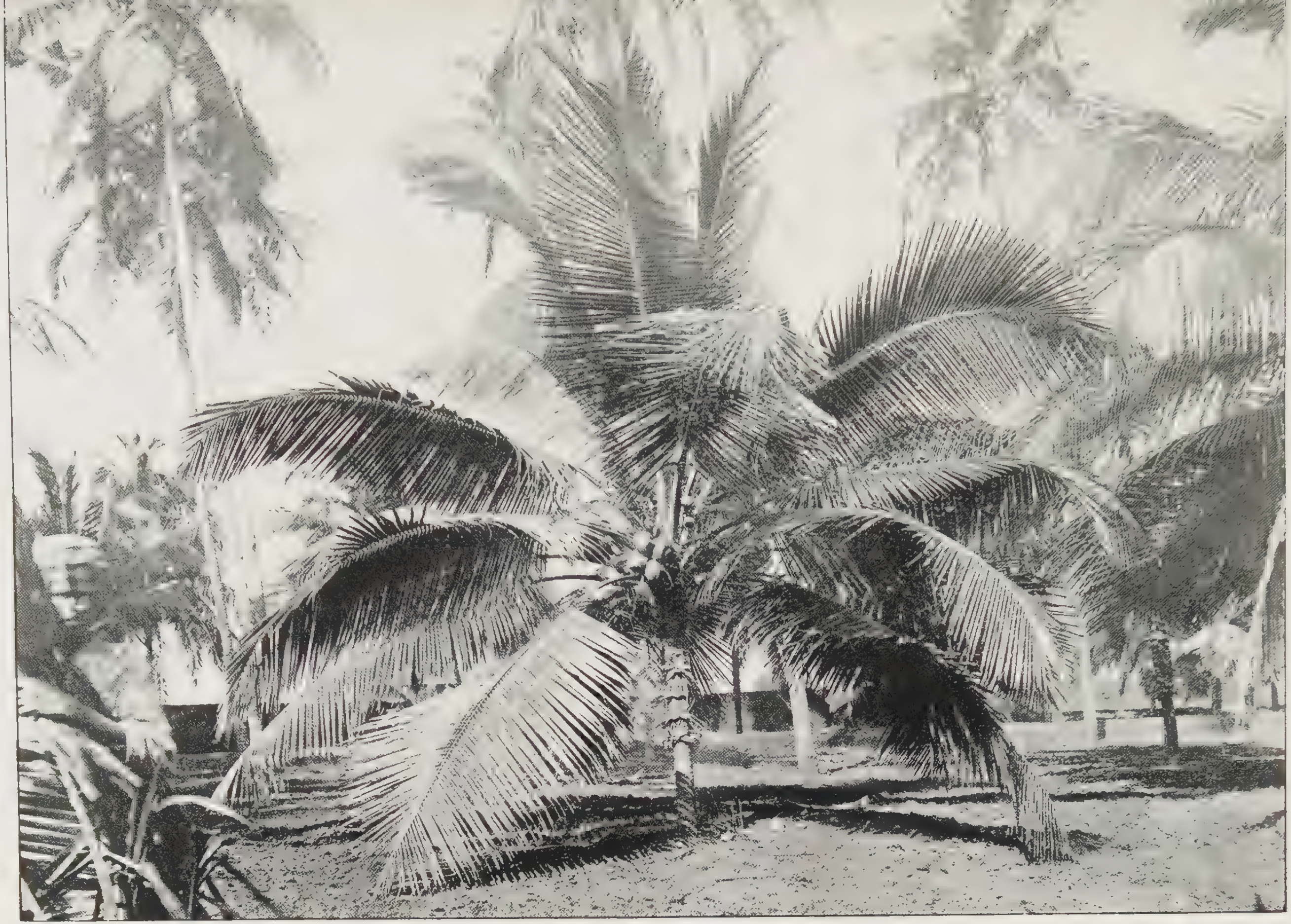
The shape of the leaf stalk is of importance and there is a certain amount of natural variation in this. The upper surface is nearly flat and merely sufficiently grooved to prevent water from running off its sides. The lower surface is a rounded keel which thickens out considerably at the base, thus forming a strong supporting bracket. This rounded keel should be deep, as a shallow keeled leaf stalk is unable to support the weight of the green bunch (Plate IX). At the same time the leaf stalk should be wide, so as to lessen the chances that the bunch will slip off its support. Plate X shows a tree with a narrow leaf stalk from off which the bunches have slipped. The leaf stalk should also



A bad type of tree. Note the weak leaf stalk, the long fruit branch stalk, and the leaf bracket unable to support the weight of the bunch.



A bad type of tree. Note the long fruit branch stalk and the narrow leaf stalk. The bunches have slipped off the supporting leaf stalk bracket.



A good type of tree. Note the short fruit branch stalk, the strong wide leaf stalk, and the bunches well supported by the leaf stalk bracket.

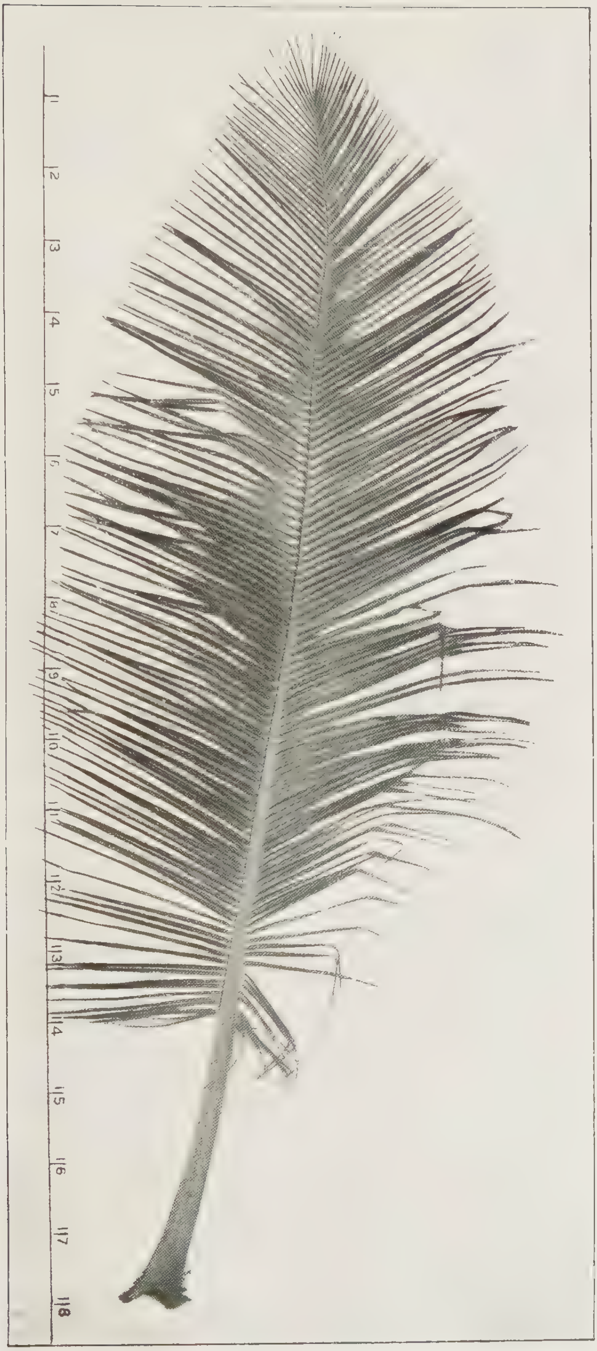
be short, as a short leaf stalk denotes a short fruit branch stalk, and if the stalk of the fruit branch is short, the bunch is nearer the stem and the strain on the leaf bracket is not nearly so great (Plate XI).

The length of the leaf of the coconut varies with the fertility of the soil, and in a tree in full vigour the length will be from 18 to 20 ft., or even longer on very rich soil. In old trees which have lost their vigour the length will be very much reduced and may not be more than 10 to 12 feet. Of this total length a little less than a quarter represents the length of the leaf stalk.

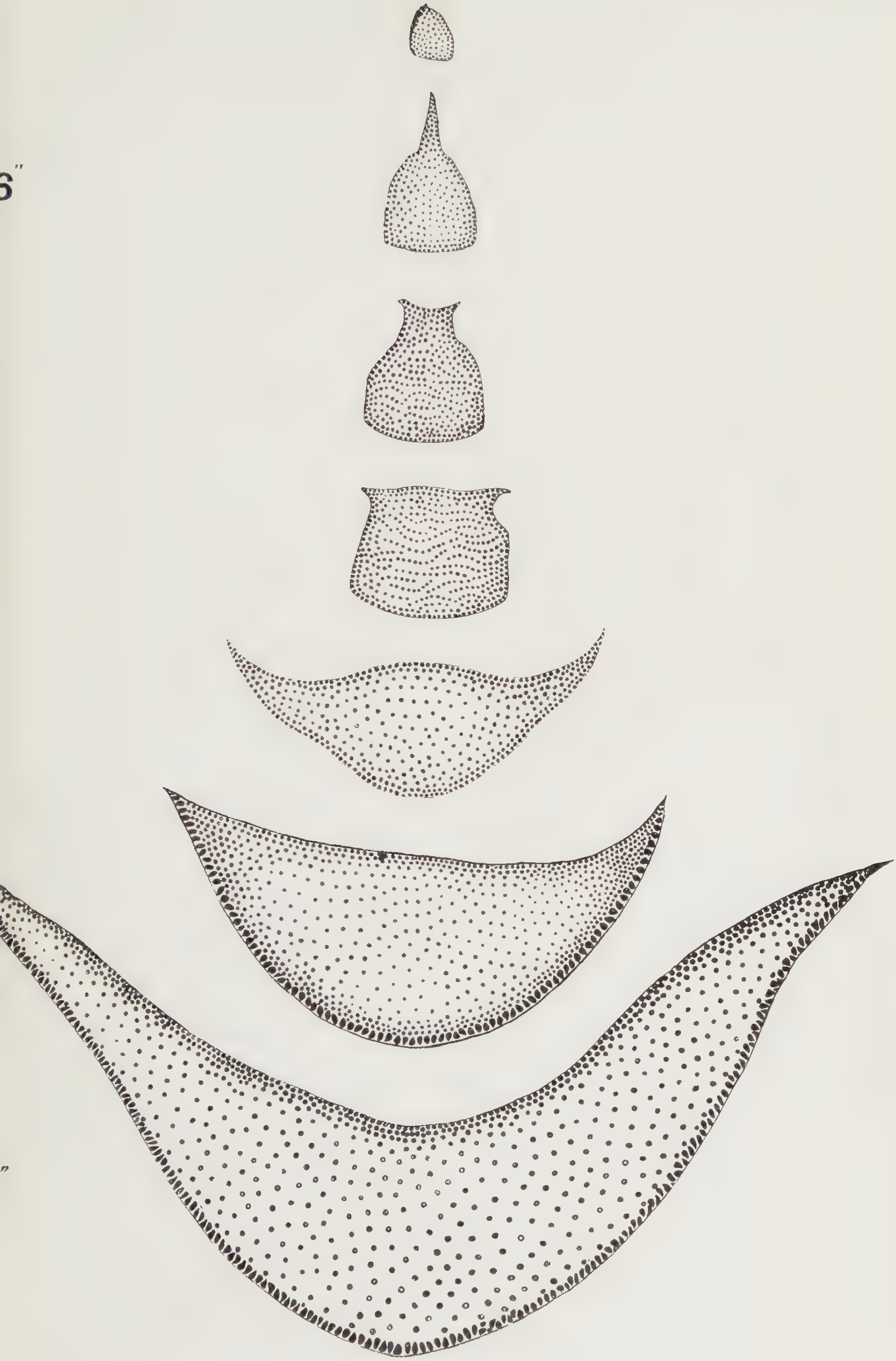
The number of leaflets on a leaf vary from about 200 to 250. Where the number is few the leaflets are usually narrow and further apart. This is an undesirable character, but it can be eliminated by the selection of seedlings in the nursery, as those plants which have the short leaf stalk have also the wider leaflets, and these arranged closer together.

The leaflets near the base of the leaf, as well as those near the apex, are much shorter and narrower than those situated near the middle. Those near the base are about 30 inches in length and about half an inch in width. Those near the apex are not more than 1½ feet in length and are less than ½ inch in width. The leaflets in the centre of the leaf are from 40 to 50 inches in length and vary in individual trees from 1½ to 2½ inches in width. It is thus clear that there is a very great variation in the area of the leaf surface of leaves from different trees, and the object of selection should be to get the greatest area of leaf surface for the tree.

Plates XII, XIII and XIV show the shape and structure of the leaf. Plate XII is a photograph of the leaf with a scale of feet alongside. The feet and inches shown in Plates XIII and XIV indicate the position on the leaf which each figure represents. Plate XIII represents cross sections of the leaf stalk at different places. This not only shows the changing shape of the leaf stalk and the midrib, but also the arrangement of the vascular strands. These strands not only give strength to the leaf but carry the sap to and from the leaf. The lowest cross section is just above the point of attachment. The peculiar shape of those strands on the lower side of the figure is of interest. These are not only larger, but are in section of a distinct wedge shape. They can thus be packed closer together. Those on the upper side of the leaf are smaller and round in section. They are much closer together than those in the centre of the leaf section as they have to withstand a pulling strain caused by the weight of the bunch stretching the upper surface of the leaf stalk. The next section is made only 1¼ inches above the first and is somewhat similar to it except that immediately above the lower layer of wedge-shaped bundles there are round closely arranged strands, similar to those on the upper side of the leaf stalk. At the two wings also there is a concentration of these bundles. Here the leaf stalk feels the influence of the wind and provision is made in its structure for countering such strains. The third section, which is taken at the place where the leaflets begin to be given off, is very similar to the last except that the wedge-shaped bundles are no longer present. Instead of one groove also there are two running parallel along the upper side of the leaf. The

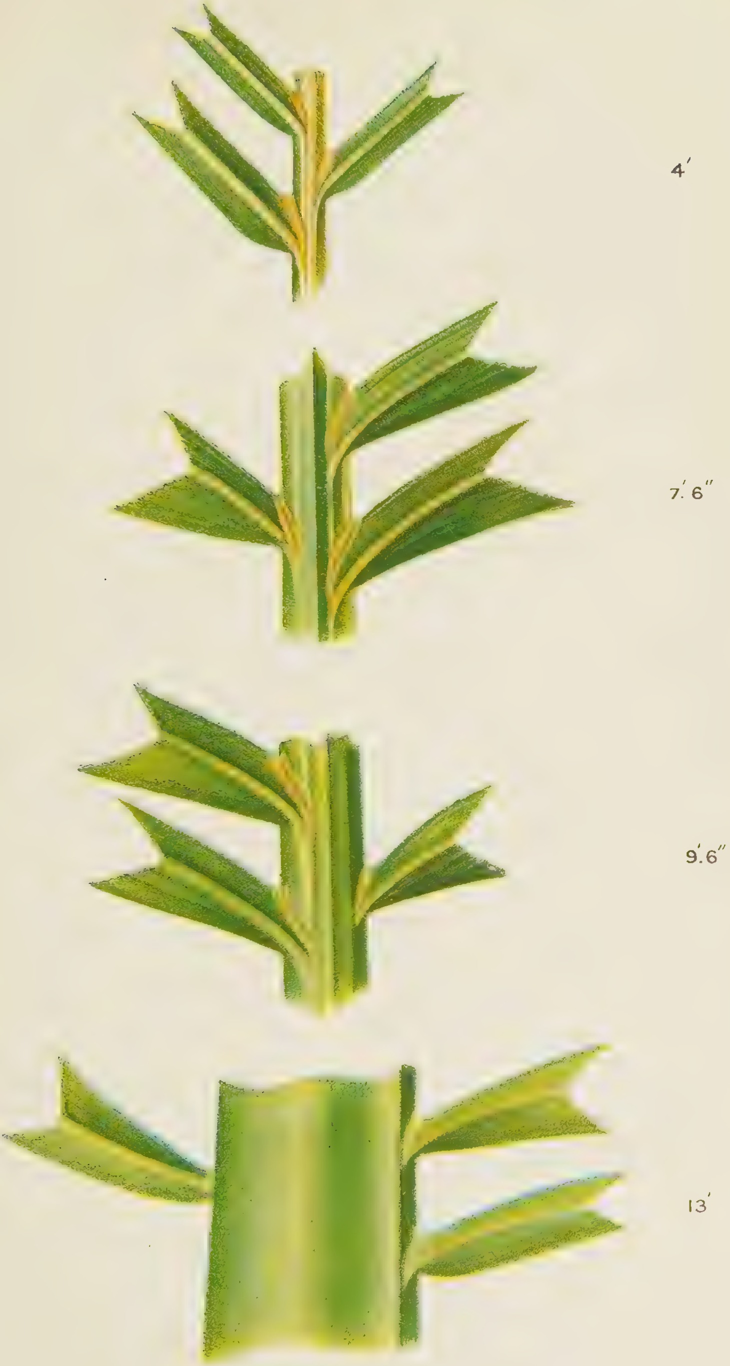


The leaf of the coconut palm (with scale in feet).



Sections through the leaf stalk and midrib.

PLATE XIV.



The attachment of the leaflets to the midrib.

fourth section at 11 feet from the apex has been made at the place where these two grooves are merging into one. It will be seen that the midrib is rising up above the place of attachment of the leaflets. The strengthening bundles are concentrated all round the section, as the leaf here has to counter strains from all directions. The section at 9 feet accentuates the projection of the midrib above the place of attachment of the leaflets, though here the two parallel grooves have merged into one. The section at 7 feet from the apex has been made at the place where this groove on the upper side of the leaf tails off leaving a prominent ridge along the centre of the upper side of the midrib and above the place of attachment of the leaflets. This ridge tapers down to nothing at 4 feet from the apex.

The upper half of the leaf is so constructed that it can withstand a strain both from above and from the sides. The groove down the centre of the midrib is of interest as this furnishes sufficient water, which is allowed to run down into the crown and from here down the stem to the base of the bole. This water prevents the centre of the crown from drying out and at the same time supplies the base of the bole, from which new roots are all the time being formed, with sufficient moisture to benefit their development.

Plate XIV shows the attachment of the leaflets at different parts of the leaf. It can be seen that this varies greatly, but in all cases the attachment is so arranged that it throws water off from the midrib down the leaflet so that it drips off the ends. In the case of the young leaves in the crown, these are more or less vertical, and in their case any rain falling on them must, no matter how the leaf were made, run down into the crown. At that part of the crown, however, moisture is essential, as here the stipules which act as bandages round the young leaf bases are still intact and must be kept moist if they are to maintain their strength.

The formation of the leaf is such, therefore, that rain falling on the crown either runs down to the centre of the crown and from there down the stem to the base of the tree, or it runs down the leaflets. There is thus a space of ground with a radius of 4 to 6 feet of the stem which receives very little moisture.

The leaflet consists of a strong midrib with a blade on each side. The blade is very tough and leathery, with a dark green shiny appearance on the upper surface. The leaflets partially close up in the shade, or in cloudy weather, or at night, while in the full sunlight a fully working leaf opens its leaflets so that there is an almost complete canopy.

The leaves are largely used in the countries where the tree is grown for roofing purposes. For small houses the midrib, with leaf stalk attached, is often used for rafters. The leaflets make an excellent thatch since the rain runs off the smooth surface of the leaf from the apex. In India these are not removed from the midrib. This is split down the middle and the leaflets on each side are cross-woven, making what is called a "cadjan." Baskets are also made, the split midrib being used as a circular frame for the basket and the attached leaflets being woven round and round and fastened off at the apex. Other articles such as hats, rain protectors,

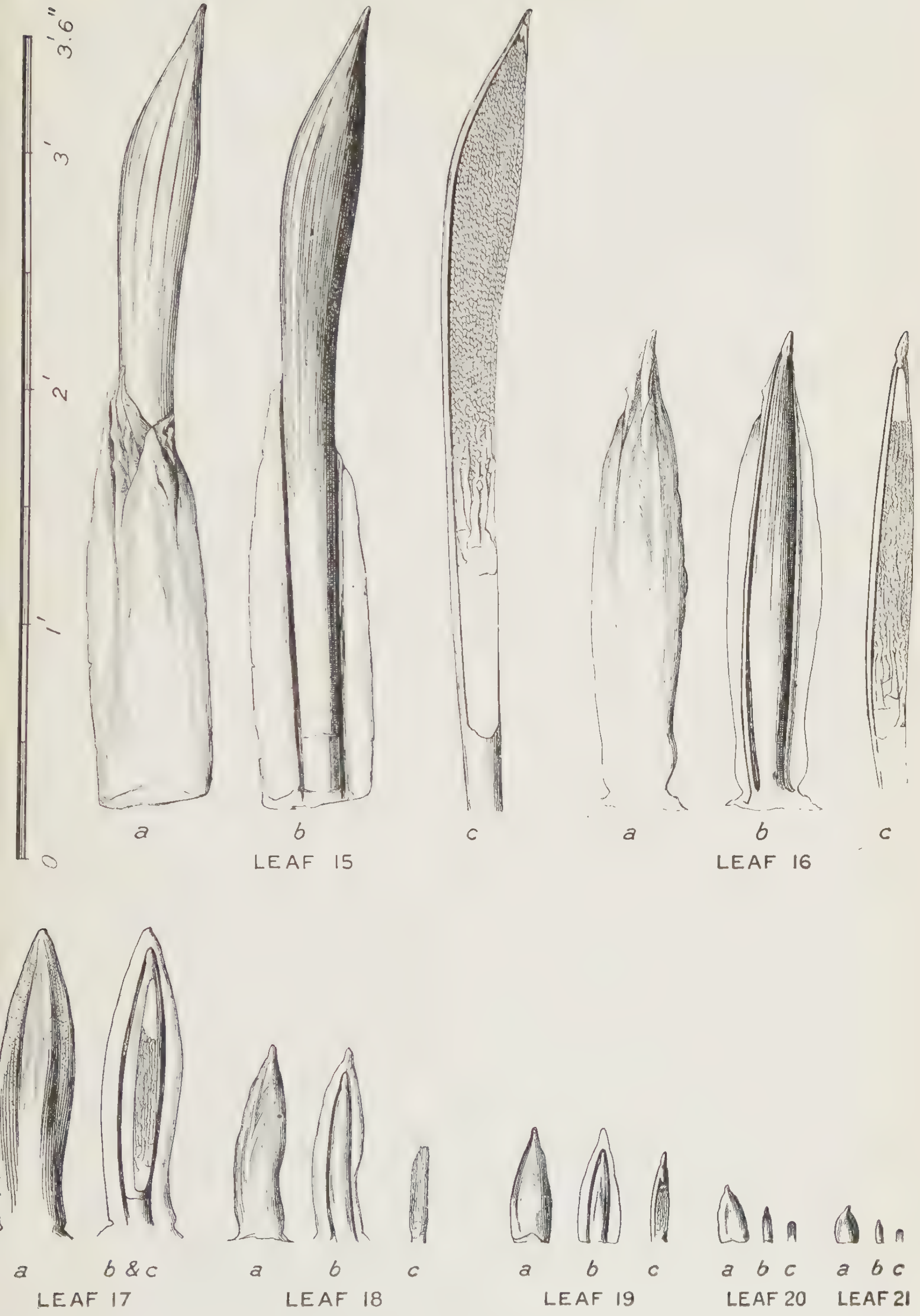
&c., are also made from the leaflets. In countries further East than India the leaflets are removed from the midrib and stitched on to a separate stick for thatching purposes. In India the leaves are a minor source of revenue from the plantation. The plaited leaves are sold and even the leaf stalk finds a sale for fuel purposes. The midribs of the leaflets are made into brooms after the leaf blades at each side have been removed. The fibrous stipule is used as a sieve for sifting meal, &c., and is said to be occasionally exported to Europe where it is used as a substitute for horse hair for stiffening clothing and furniture.

THE FLOWERING BRANCH AND THE FLOWER.

When once a tree has commenced to flower, each leaf formed after that time normally produces a flowering branch in the leaf axil. Theoretically, therefore, the number of leaves produced on a bearing tree and the number of flowering branches are the same.

The flowering branch is what is known as a spadix. That is to say it is a branch the whole of which is produced at one and the same time. Plate XV illustrates the development of the spadix and shows to scale the spadices in seven consecutive leaf axils. The leaf numbers correspond to those in Plate VIII and are described in the text on p. 40. Leaf No. 21 in this particular case is the last formed fully developed leaf on the tree. The spadix in its leaf axil, however, is still very small. That in the axil of leaf No. 15 is fully developed and just ready to open. The three illustrations of this spadix show the different parts. The young spadix is enclosed within two covering leaves or spathes. The outer one ceases to grow some considerable time before the flowering branch is fully grown. The inner spathe, however, continues to grow till the flowering branch is ready to open. It is furnished with a hard point and forces its way through the outer spathe. Leaf 15 (fig. *a*) in the plate illustrates this. Leaf 16 (fig. *a*) shows the inner spathe just breaking through the outer spathe. The inner spathe is deeply ribbed and

PLATE XV.



The development of the bud of the flowering branch

grooved and this allows it to expand in girth as the inflorescence within swells. Finally it splits along one of these grooves and liberates the flowering branch. Frequently this will split along the upper side of the spathe, and if this happens the whole spadix turns round till the inflorescence within falls out.

The flowering branch consists of a main stem with some thirty to forty branches, and a portion of this is shown in Plate XVI, fig. 1. The lower part of these branches is bare for two or three inches and the rest of the branches is thickly studded with sessile flowers. These, with the exception of three or four near the base, only develop the male organs of reproduction. The female organs are there but are only rudimentary. The female flowers are always situated at or near the base of the flowering branch or spikelet. It is rarely that their number exceeds five, and much more often there are from one to three. Sometimes they are entirely absent, especially on the upper branches of the inflorescence. The flowers are all seated on cushions. Those on which the female flowers are seated are very prominent, while those on which the male flowers rest are small, sometimes two or three of these latter resting on the same cushion. If there are female flowers on a branch of the inflorescence, one of these is always the lowest flower on the branch. Usually, however, there is a male flower on each side of it resting on the same cushion. The lower male flowers are often in pairs resting on the same cushion. The total number of flowers on each branchlet will amount to between 250 and 300. After the flowers have dropped there will be from 150 to 175 scars indicating where these flowers were attached. The number of female flowers on an inflorescence is very variable. Sometimes these are entirely absent. This is specially the case with young trees when they first commence to flower. It may also happen when a tree has been bearing very heavily and requires a rest. On an average there may be from twenty to forty, though the writer has counted as many as 235 female flowers on one inflorescence.

When an inflorescence has burst out from the spathe, the flowers do not all open at the same time. Flowering commences with the male flowers at the apex of the terminal branches of the inflorescence and gradually extends to those lower down, though always commencing at the apex of these. It takes some twelve to fifteen days for all the male flowers on an inflorescence to finish flowering, and as these fade they drop off. It is only after the male flowers have finished flowering and dropped that the female flowers commence to open. In this case also the flowering commences with those flowers on the terminal branches and gradually extends to those on the lower branches. It takes from twelve to fifteen days for all the female flowers on a normal inflorescence to finish flowering, and it very rarely happens that the next inflorescence bursts from the spathe till the flowering on the previous one is over. Thus there is very little chance that the pollen from the male flowers of an inflorescence will fertilize the female flowers of the same inflorescence, and there is also very little chance that the pollen from the male flowers of the following inflorescence will fertilize the female flowers of the previous inflorescence on the same tree. From this it is clear that the fruit of the coconut is usually cross fertilized, and this explains why it is that there is so much variation in the seedlings grown from nuts harvested from the same tree and even from the same bunch. The male parent of the seed nut and the male parent of the tree from which the seed nut has been gathered are unknown. This explains why there are so many so-called varieties of the coconut and why it is impossible to differentiate between them. Varieties, such as they are, are formed by large numbers of trees having the same origin, and therefore being related, being grown in the same locality. This gives a certain amount of uniformity. It is true that there are certain dwarf and early maturing varieties which, if grown in compact blocks, can keep themselves more or less true to a general type, but there are always signs of crossing among these if other coconuts are grown in the neighbourhood. There are also some of the ornamental varieties of coconuts with brightly coloured fruit which sometimes breed true. These, however, do not form any appreciable amount of meat. The rate of bunch production, therefore, is more rapid than in copra varieties, and in this case it is possible for the male flowers in the next inflorescence to open before the female flowers of the previous inflorescence have finished flowering. At the same time such trees should not be allowed to grow near trees from which seed nuts are to be gathered, since if these two cross, the progeny will give nuts which may be useless for copra production.

The male flower consists of a perianth of six leaves. Three of these are small basal scale leaves and within and alternating with them are three irregularly shaped pointed horny sepals. These form the calyx, and this encloses the three stamens each of which bears two anthers or pollen sacks. In the centre are the rudimentary female organs, which do not develop. These pollen sacks usually burst and shed their pollen before the sepals open. Until these open the flower is hermetically sealed. The flowers which are about to open can easily be recognized by their being more opaque than those which are not ready to open. If one of these is opened and the pollen grains are immediately transferred to a slide and examined under the microscope, these will be seen to be round. Within a few seconds, however, these change with the change in the moisture conditions of the atmosphere and assume a shape which appears under the microscope to be a pointed oval with a groove down the middle—somewhat in appearance like a grain of wheat. If such pollen grains are wetted they at once assume a rounded shape and commence to disintegrate within the space of two or three hours. It is thus evident that, in the moist tropical climate which favours the growth of the coconut palm, there is no chance of the shed pollen grains remaining dormant till the female flowers are open and receptive. It is possible to preserve these pollen grains for several days in hermetically sealed tubes without their losing their vitality. This is a matter which requires further investigation as it may lead to a system of artificial pollination which will ensure the parentage of the seed nuts. This is probably of greater importance in the case of the coconut than of any crop grown, when one considers the profitable life of the palm.

The female flower consists of a perianth of six scale leaves which enclose the three carpels, each of which contain an ovule. These ovules are enclosed in a fibrous fruit wall, which exists before the flower opens. The ovules are situated at the base of this protective covering. At the apex of the carpels are three stigmas corresponding to the three carpels below. When the flower is about to open the stigmas swell, turn white in colour, and when the flower actually opens they expose a sticky viscous surface in the triradial opening. They are then receptive. Apparently they do not remain receptive for long as they have a strong scent in the early morning which soon passes off in the heat of the day. This scent, which both the male and the female flowers possess, is distinct and of the type which usually attracts insects, such as that of the "Moonflower" and the Datura. The female flower also possesses three honey glands, whose ducts open near the apex of the fruit coat and alternate with the stigmas. These honey glands are situated at the base of the flower, and the remains of the ducts can be seen even in the ripe fruit and seem to grow with the fruit. This is clearly shown in Plates XVII and XVIII.

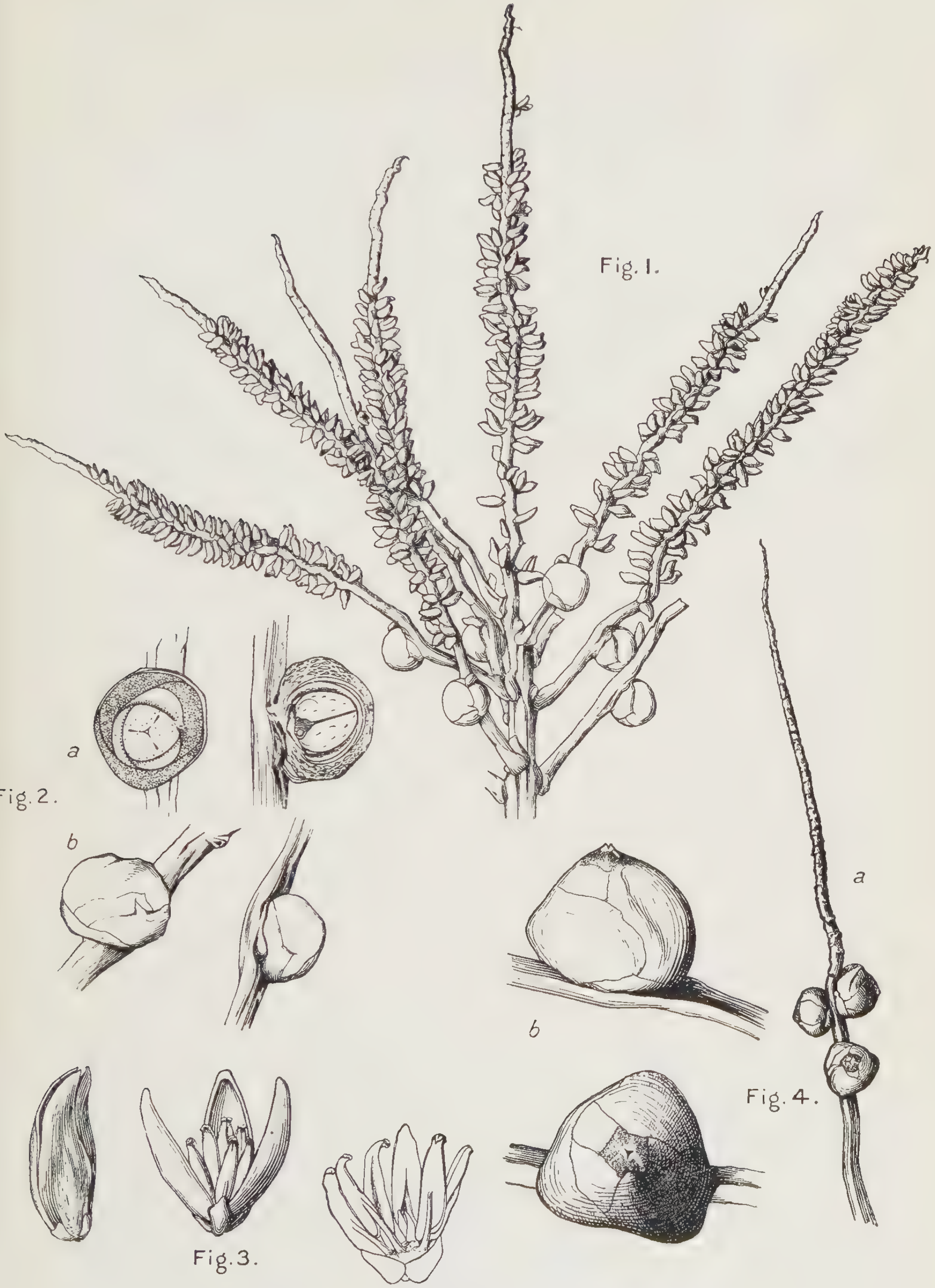
From these honey glands there exudes a sweet liquid which, if the flowers are hanging downwards, will run on to the receptive stigmas and can be seen from the ground as a glistening drop in the sunlight. It is thus evident that Nature has intended that the flower should be fertilized by the aid of insects.

Normally only one of the ovules develops and forms the nut, but very occasionally two and even all three will develop. When this happens, the fruit forms a hard separating wall or septa between the different carpels.

The length of the whole inflorescence is from 3 to 4 feet. Any difference in the length is due mainly to the length of the stalk of the inflorescence, and this is a point to remember when selecting trees from which to save seed nuts.

Plate XVI illustrates the various parts of the flower and inflorescence. Fig. 1 shows a part of the inflorescence. Some of the male flowers have already shed from the tips of the branches. The buds of the female flowers are to be seen at the base of the branches of the inflorescence. Fig. 2 (*b*) is an enlargement of the female flower buds. The cushion on which the flower rests can be seen as also the scale leaves of the perianth which completely cover the fibrous fruit coat within which the carpels are enclosed. Fig. 2 (*a*) shows a transverse and a longitudinal section through the female flower bud. The cross section shows the arrangement of the six leaves of the perianth, the central passage from the stigma to the ovules, and the three honey ducts. The longitudinal section shows how the fruit is entirely protected by the scale leaves of the perianth while the female flower is in bud, and the position of the ovule with the style leading up to the apex of the fruit. Fig. 3 shows the male flower before it is open, the male flower when it is open with the six anthers within, and the male flower with one of the protective scale leaves of the perianth and one of the stamens removed to show the rudimentary female organs in the centre. Fig. 4 (*a*) shows the condition of the inflorescence when the

PLATE XVI.



The coconut flower.

Fig. 1.—A part of the flowering branch. Fig. 2.—The female flower bud: (*a*) in section, (*b*) entire. Fig. 3.—The male flower. Fig. 4.—(*a*) As the branchlet appears when the female flowers open, (*b*) different aspects of the female flower.

female flowers open. Three flowers are shown on one branchlet from which all the male flowers have shed. Fig. 4 (*b*) shows the female flower when it is in flower. The upper

GRAPH A.—Showing the Seasonal Variation in the number of female flowers formed in each consecutive bunch and the number which ripen fruit (average of twenty-five bearing trees).

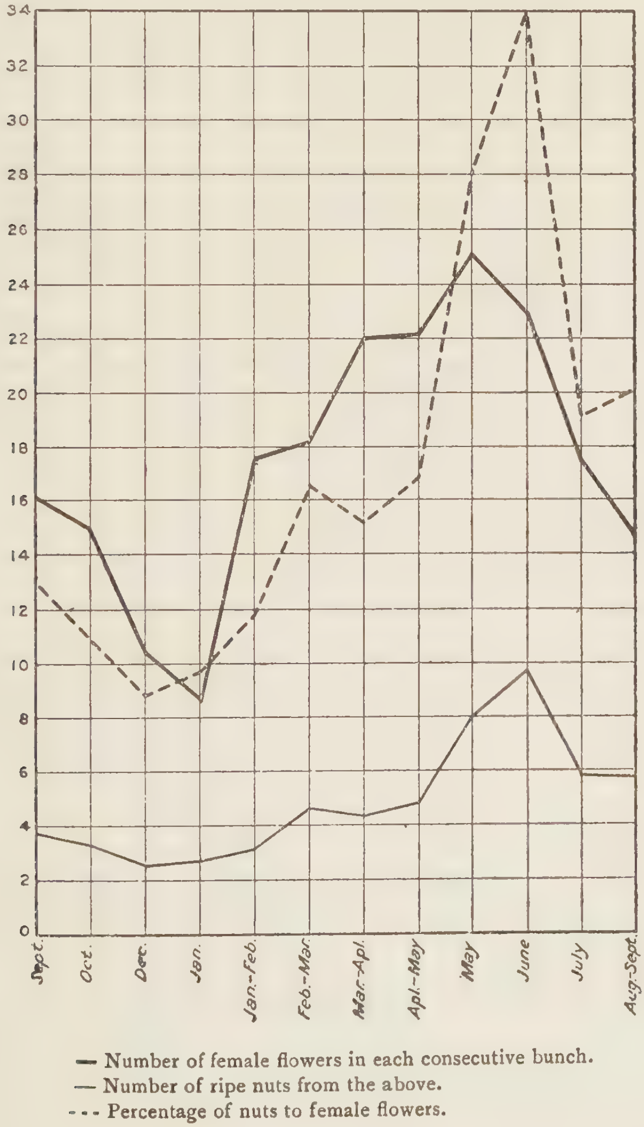


figure shows the fruit coat emerging from the perianth and the three swollen lips of the stigma. The lower figure shows the triangular opening in the centre of the flower and the three ends of the honey gland ducts radiating from the centre behind each stigma.

There is a distinct seasonal variation in the proportion of female flowers which set and in the number which develop. This variation will, of course, differ in different countries. On the Malabar Coast of India this is very marked and is shown on the graph on page 57. This graph represents the average crop for one year of twenty-five trees which have regularly borne a bunch of nuts in each leaf axil. It shows the number of female flowers on each bunch, the number of nuts on the same bunch and the percentage of female flowers which set and produced fruit. It will be seen that the greatest number of female flowers are produced on bunches which open in the months of May, June and July, that the largest number of nuts set in the months of May and June, and that the percentage of female flowers which set is also highest in these two months. Similarly the smallest number of flowers, the smallest number of nuts to set, and the smallest percentage of nuts to set are in the months of December and January.

A study of the average rainfall for the year, which is given on p. 35 helps to explain this seasonal variation. December to March is practically rainless. There are a few refreshing showers in April and May. The monsoon sets in in the first week of June and continues till the middle of August, during which time the skies are densely clouded.

September, October and November bring bright showery weather. It is evident that transpiration and carbon assimilation must be at its minimum during the monsoon, which means that the tree is neither taking in appreciable quantities of plant food from the soil, nor is it manufacturing carbohydrates from the air. It has therefore to utilize such plant food that it has stored up in the tree for the development of the crown and the flowering and fruiting branches. By the end of the monsoon this reserve must be considerably depleted, and during the following months it has not only to replenish this reserve, but to supply what is required by the tree. It is during these months of bright weather that a fresh reserve is gradually made up again. Its effects are not however immediately seen in the increase in the number of flowers which form and the number that set because the number of female flowers which develop is determined some four to five months prior to the spathe opening. This is proved as follows. It is almost invariably found that, where a tree has set two or three good bunches in succession, the fourth or fifth bunch which follows carries a much smaller number of female flowers than the preceding ones. That is to say the setting and swelling of the fruit has a considerable influence on the number of female flowers on subsequent bunches which develop. The converse of this is also true. Where a tree has been bearing bunches in succession with a small number of nuts, the fourth or fifth bunch which follows shows an increase in the number of female flowers which it develops.

Referring to the graph again the fruiting curve shows that the least number of fruit set in the months of November, December and January. On this basis the tree should produce the greatest number of female flowers in the months of April, May and June, which is the case. The greatest number of fruit set in the months of May, June and July, and the graph shows that there is a rapid falling off in the number of female flowers formed in the bunches which open in October, November and December.

The table on the opposite page shows the reconstruction of the crop on a typical tree, each vertical column representing the crop on the tree after the opening of each new flowering spathe.

This clearly shows that a period of heavy setting is followed by a steady decrease in the number of female flowers which develop in bunches which subsequently open and vice versa. The number of female flowers on every seventh bunch is alternately high and low. Where it is preceded by heavy setting, the number is low, and where it is preceded by light setting the number is high.

The graph on page 62 shows the variation in the yield of trees from season to season. It represents the average yield of one hundred trees which have regularly borne a fruiting branch in each successive leaf axil. The year 1918 was one of very short rainfall when the monsoon practically failed. Instead, therefore, of having cloudy weather throughout June, July and August, there was bright sunshine most of the time. This meant that the trees had a much longer period than usual in which to take in plant food from the soil, and to assimilate carbo-hydrates. The result of this is seen in the crop of 1919, which not only gave bigger bunches from

February on till October, but continued to produce heavier bunches right on till August, instead of stopping in June. The 1919 monsoon was normal, and the crop in the following year has got back to its normal rate of seasonal variation, i.e., producing its smallest bunches in January, and its largest bunches in May and June.

Tree No. VIII, 23.

Number of females flowers in the bunch :—

77 44 17 28 30 27 13 21 26 33 45 54 63 54 32 29 22 16 13 17

Number of nuts which set in the bunch immediately preceding :—

3 12 16 11 17 9 5 6 8 6 7 12 9 11 28 19 16 7 7 9

Do. 2nd do. :—

17 3 12 16 11 17 9 5 6 8 6 7 12 9 11 28 19 16 7 7

Do. 3rd do. :—

7 17 3 12 16 11 17 9 5 6 8 6 7 12 9 11 28 19 16 7

Do. 4th do. :—

9 7 17 3 12 16 11 17 9 5 6 8 6 7 12 9 11 28 19 16

Do. 5th do. :—

10 9 7 17 3 12 16 11 17 9 5 6 8 6 7 12 9 11 28 19

Do. 6th do. :—

8 10 9 7 17 3 12 16 11 17 9 5 6 8 6 7 12 9 11 28

Do. 7th do. :—

10 8 10 9 7 17 3 12 16 11 17 9 5 6 8 6 7 12 9 11

Do. 8th do. :—

? 10 8 10 9 7 17 3 12 16 11 17 9 5 6 8 6 7 12 9

Do. 9th do. :—

? ? 10 8 10 9 7 17 3 12 16 11 17 9 5 6 8 6 7 12

Do. 10th do. :—

? ? ? 10 8 10 9 7 17 3 12 16 11 17 9 5 6 8 6 7

Do. 11th do. :—

? ? ? ? 10 8 10 9 7 17 3 12 16 11 17 9 5 6 8 6

Do. 12th do. :—

? ? ? ? ? 10 8 10 9 7 17 3 12 16 11 17 9 5 6 8

Do. 13th do. :—

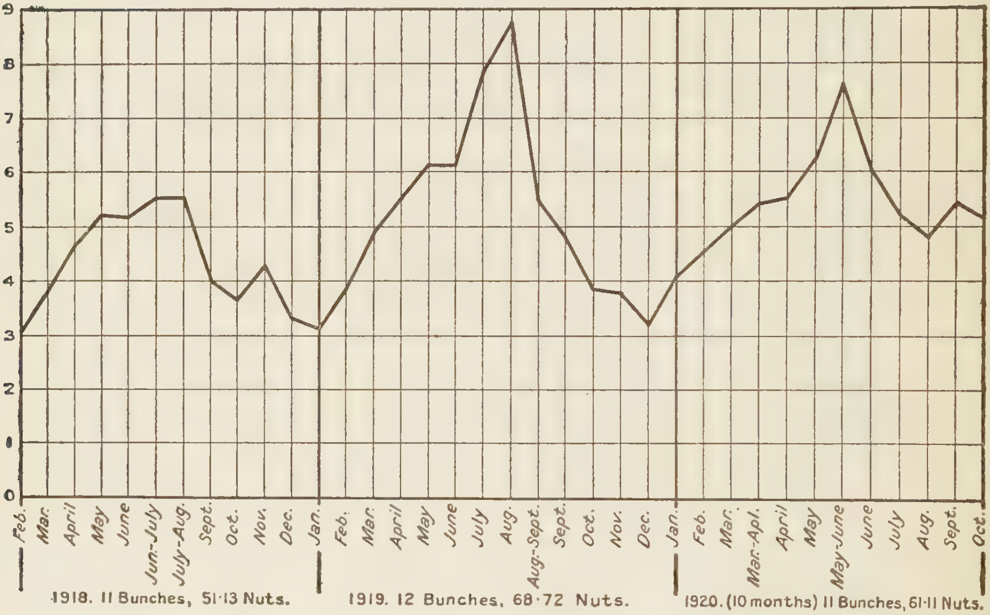
? ? ? ? ? ? 10 8 10 9 7 17 3 12 16 11 17 9 5 6

Do. 14th do. :—

? ? ? ? ? ? ? 10 8 10 9 7 17 3 12 16 11 17 9 5

There is much variation also in individual trees. Some trees never produce a large number of female flowers, but at the same time set a high proportion of these. These trees do not show these seasonal variations to anything like the same extent as the average tree. The result is that one finds much steadier cropping in such cases. The following is an example of such a tree :—

Graph B.—Showing the Seasonal variation in the number of nuts which set in each consecutive bunch (average of 100 regular bearing trees).



Tree No. VIII, 37.

Number of female flowers produced :—	14 14 15	14 11 9	16 24 22	20 15	16 15 13 16	14 13	11 16 18
Number of fruit which set :—	6 6 6	7 5 5	7 8 8	8 6	9 5 6 6	4 5	3 7 9
Approximate date of flowering :—	Feb., 1918	May, 1918	July, 1918	Oct., 1918	January, 1919	Mar., 1919	May, 1919

Other trees again are very irregular in bearing and may at one time bear very heavily while at others they bear practically nothing. The following is an example of such a tree. After failing to produce any flowering branches in eight consecutive leaf axils from December, 1917, till the following May, it then commenced to flower and set fruit freely as is shown below :—

Tree No. VIII, 22.

Number of female flowers produced ;—	9 40 57	57 63	79 69	95 89 88 180	154 169 232 157	97 115 91
Number of fruit which set :—	9 26 24	39 35	28 28	23 18 6 4	2 3 2 0	0 6 2
Approximate date of flowering :—	June, 1918	July, 1918	Oct., 1918	January, 1919	May, 1919	July, 1919

After this effort the tree produced eleven inflorescences, which only bore male flowers. The tree had evidently quite exhausted itself. Some idea of what amounts of plant food are required by the growing fruit can be gauged from the chapter on manuring on page 181.

The stalk of the inflorescence contains a very useful straight fibre, though the only use the writer has ever seen made of it is to make local whitewash brushes. This is done by shaving off the outer rind of the part required for the brush and then beating out the end. The result is very similar to the ordinary fibre paint brush. The stalks of the branches of the inflorescence are used by the natives of India for toothbrushes. These are cut off square and the cut end is then scraped to expose the ends of the fibres. When fresh these, being astringent, form an excellent substitute for a tooth brush.

The inner spathe also contains a long straight fibre which does not seem to have been made use of except locally. These are sold in the bazaars of South India, and when soaked in water and split into convenient thicknesses, are used in the place of rope for tying on the reepers for the roof of a house, for tying on "cadjans" on to the reepers, for tying fencing together, &c. The great advantage that this has over ordinary rope is that it will stand the weather well.

If the inflorescence is not allowed to open, which can be done by tying this up with rope or fibre, and if the end is cut off and the wound is not allowed to heal, a sweet liquid exudes. This juice is collected in vessels and ferments in the process of collection. This is known as "toddy." If it is not allowed to ferment, which can be effected either by sterilizing the collecting vessel or by coating the inside of it with freshly slaked lime, the sweet juice known as "sweet toddy" can be boiled down and crude sugar or "jaggery" is obtained. Fresh fermented "toddy" is commonly used in place of yeast for breadmaking. Vinegar can also be prepared from the fermented "toddy," and if fermented "toddy" is distilled, a spirit known in the East as "arrack" is produced.

THE FRUIT AND ITS DEVELOPMENT.

The receptive surface of the stigma furnishes a suitable medium for the germination of any living pollen grains which may adhere to it. When these germinate they send out a tube known as the pollen tube, which grows down the style to the ovule at the base, which it fertilizes. With this seemingly haphazard method of fertilization, it can be readily understood that a large number of the female flowers never get fertilized at all. Fertilization is largely, if not entirely, done through the agency of bees, but there are many other insects which visit the female flowers for the sake of the nectar, but which do not bring pollen with them at the same time. Several species of ants are to be seen visiting these flowers, and these will drive off the bees, many of which are very small and stingless. Among the ants must be mentioned the "red ant" (*Oecophylla smaragdina*) as being specially harmful in preventing the female flowers from being fertilized. This ant specializes in "meally bugs," and it locates colonies of these on the spathe, just before this is ready to burst. As soon as the spathe bursts and the inflorescence is liberated, these "meally bugs" are transferred to the branches of the flowering branch, and the ants then proceed to spin a web enclosing the whole of the centre of the inflorescence where the female flowers are situated. This entirely prevents other insects from visiting the flowers, and very few, if any, of the female flowers set.

Great damage is also done by the larva of one of the micro-lepidoptera. Apparently the eggs are laid on the female flower or flower bud, and the larvæ, when they hatch out, bore their way into the female flower. Their favourite point of attack is the soft sweet tissue along the line of the style, which they fill with droppings. At other times they bore into the soft tissue where the honey ducts are situated and from here make for the style. At other times they bore in between the scale leaves of the perianth and the tender fruit coat and usually reach some vital part of the flower.

Then again, many of the female flowers may set, but the tree is unable to cope with such an amount of young fruit, and these may fall although they have been fertilized, and in many cases the number of female flowers is far in excess of the maximum number that could be contained on a bunch. The largest number of nuts recorded on one bunch by the writer is 52, while frequently there may be from 100 to 200 female flowers.

Normally the number of female flowers which set will be about 25 per cent. of those formed, while it may rise to 50 per cent. in the case of trees which do not form an excessive number of these.

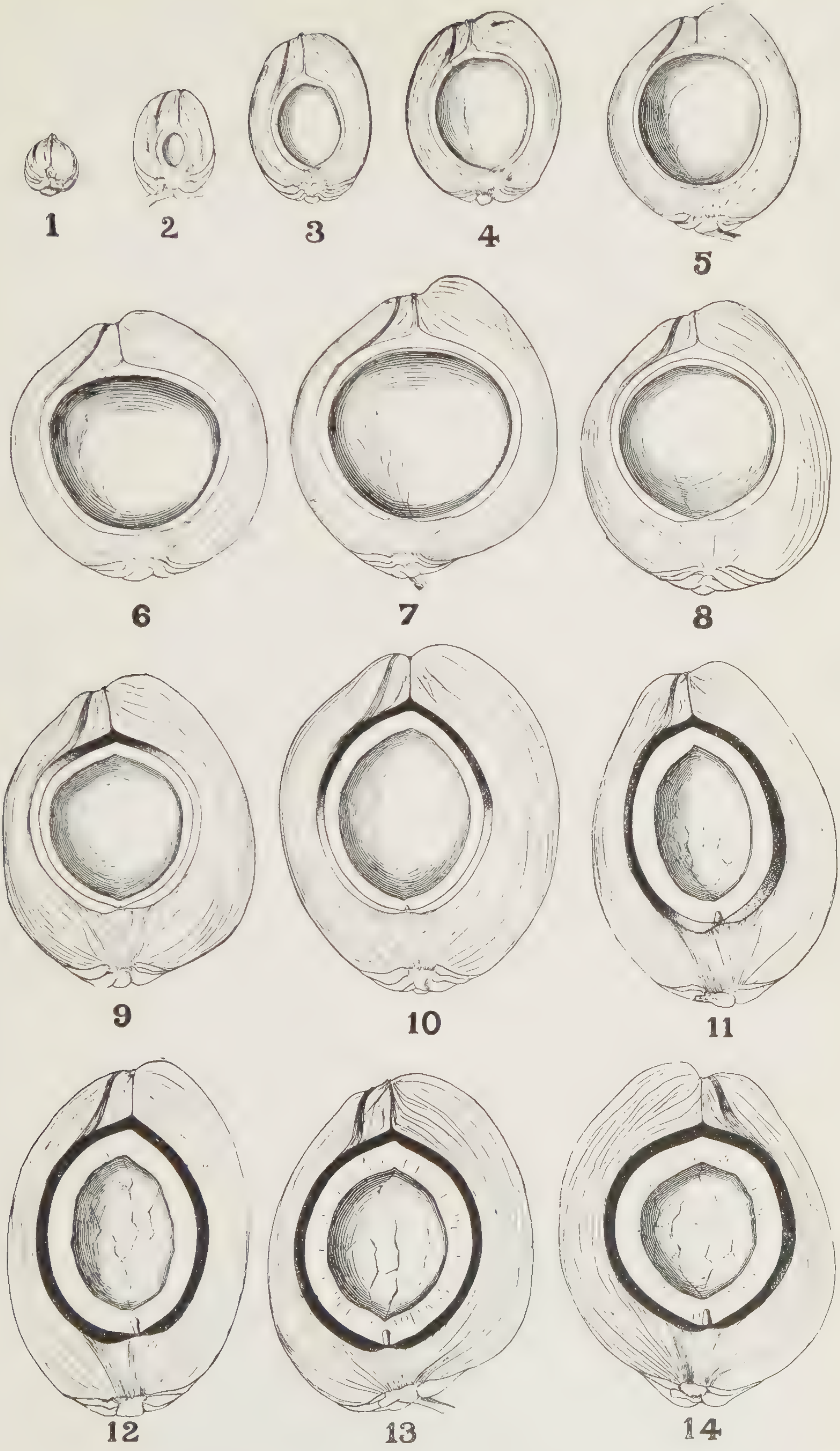
After the fruit has properly set, which will be about fifty days after the flower has faded, very few of the fruit will fall till they are ripe. Occasionally the tree finds that it cannot ripen all its fruit and then produces barren fruit. The shell may be partially formed and even some of the meat laid down when work ceases, but such fruit usually stay on the tree for the normal period of ripening. If nuts do fall it is not because the tree is incapable of feeding and ripening that number. Sometimes the fruits are too crowded on the bunch and there is not room for them all to develop. One or more will be crowded off. On trees such as that shown on Plate X, where the fruit branch stalk is very long and the leaf bracket is narrow, the bunch will slip off the support. If it is a heavy bunch it will almost certainly buckle from the weight of the green fruit. This will naturally check the flow of sap to the young fruit and these will fall from lack of nourishment. Small cultivators who know their trees will usually support such bunches while they are still young, either by tying them up to the leaf above or by supporting them from below by means of a short length of leaf stalk. On a large estate this is not feasible, and the only remedy is to carefully discard all such seedlings which have a long leggy leaf stalk when planting out from the nursery.

When the female flower fades the stigmas turn a pink-brown colour, and if the ovule has been fertilized the fruit commences to swell. Plates XVII and XVIII show the development of the fruit. In each plate the nuts are arranged in the order in which they have been formed, and each represents a nut from each bunch of a regular bearing tree, i.e., one which has developed a bunch for each leaf formed. Plate XVII shows the nut cut lengthwise and Plate XVIII shows the nut cut across the middle of the fruit. The dotted line on the latter shows the maximum girth of the fruit. In each diagram there are fourteen nuts, and taking the time for the fruit to grow and ripen as twelve months, the difference in the age of successive fruits averages twenty-six days.

In the early stages of development, the growth of the fruit coat is most rapid. This is probably to give greater protection to the young ovule, which is situated at the base of the fruit, as the growth is mainly confined to the extremity of the nut away from the stem. The base of the fruit is already well protected by the scale leaves of the perianth, which persist and continue to grow as the fruit develops. It will be seen also that the duct of the honey gland continues to grow along with the fruit, though what purpose it serves is not evident, unless it is that it assists in forming the ribs which are seen on the ripe fruit and which indicate the separation of the three carpels. The interior of the nut is completely filled with liquid until after the fruit commences to ripen. This is used to help to form the meat, and, as this becomes fully formed, a further supply is not required and it then commences to fail. This liquid, or as it is called "coconut water," has a pleasant sweet taste and is very rich in phosphates and potash.

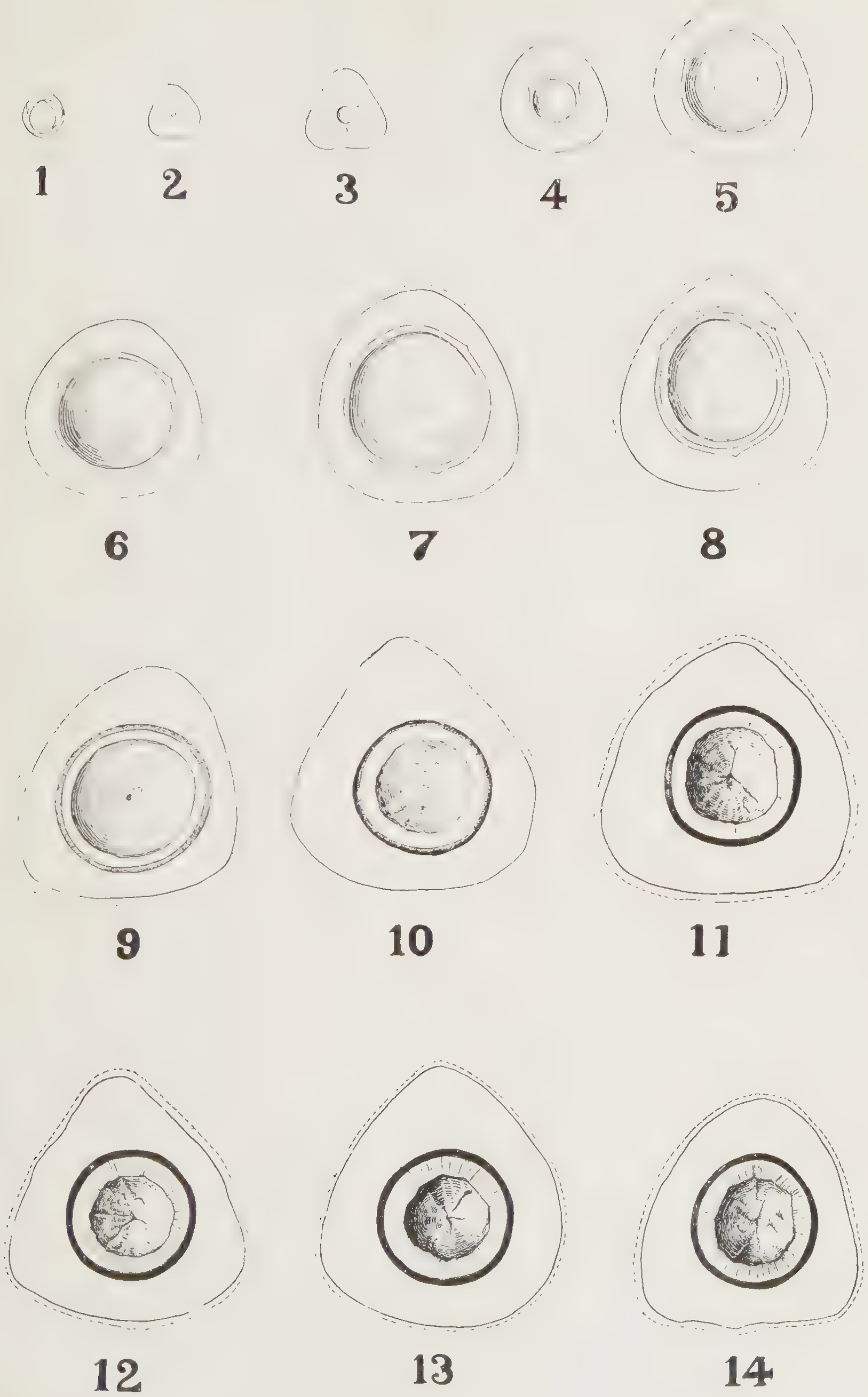
As soon as the nut has been fertilized, it commences to form the shell. This is seen clearly in the cross section of the first fertilized fruit. The three points of this represent the position of the duct of the honey gland. At this stage the shell is quite soft and of a creamy white colour. The husk and shell continue to grow till six or seven nuts younger than itself have been formed. The fruit has then reached its full size and is probably bigger in diameter then than when it is actually ripe and the husk has contracted. Although the diagram shows that the nut itself at this stage is bigger than the ripe nut this is probably incorrect, since

PLATE XVII.



The development of the coconut from the ovule to the ripe fruit (longitudinal section).

PLATE XVIII.



The development of the coconut from the ovule to the ripe fruit (transverse section).

the sixth, seventh and eighth nuts from the youngest would, if they had remained on the tree, have been harvested in May, at which time of the year on the Malabar coast the fruits are bigger than at any other time. Until the fruit has reached its maximum size, no attempt is made to form either the endosperm or the embryo. The endosperm is seen for the first time in the seventh nut from the youngest, and commences to form at the end of the fruit away from the point of attachment to the fruit branch (Plate XVII, No. 7). At this stage the endosperm or "meat" is a soft gelatinous substance. Two nuts older than this the "meat" has formed all round the inside of the shell and the young embryo can be seen at the end of the fruit next to the place of attachment, i.e., at the end of the fruit where the meat is last formed. At this stage the shell of the nut has commenced to harden and to change from a creamy white to a brown colour. Here also the hardening process starts at the end of the fruit away from the place of attachment to the stem. The germ or embryo is situated immediately under what is known as the "soft eye," and here the shell is quite thin and even in the ripe nut can very easily be pierced. The twelfth oldest nut is fully developed, the germ is full grown, and the shell, except for a small portion round the germinating eye, is completely hardened. The thirteenth and fourteenth nuts are fully developed although the husk is still green.

From this we get the following data :—

When the nut is about 168 days old it is full sized and the meat has just commenced to form.

When about 224 days old, the shell has commenced to harden; the meat has formed all round the inside of the shell; the germ is visible.

When about 308 days old the meat is fully formed, but the shell has not completely hardened.

When about 364 days old the shell has fully hardened and the nut is ripe.

There is a considerable difference of opinion in different countries as to when the nut is ripe for harvest. In some places it is the practice to allow the nuts to drop of themselves from the tree. In others, though they are not actually allowed to drop, they are not harvested till the outer covering has completely dried. In other countries again the nuts are picked when the husk is still green. This last is the practice in Ceylon as well as in Southern India for all except seed nuts, and both these countries are noted for the quality of their copra.

Much depends on the season and the local conditions as to when is the best time to harvest. In dry weather no harm is done by leaving the nuts on the tree till they fall, but where there is showery weather, the attachment of the nut to the fruit branch does not dry up and the nuts will hang on to the trees till long after they are ripe. In fact it is no uncommon thing to see nuts hanging on the tree when these have reached the stage of germination which would occupy three or four months in the nursery. In a dry climate or after a long spell of dry weather there is no harm done, since, as soon as a rain falls, any nuts which are dead ripe will fall of their own accord. If labour is available which is accustomed to climb the trees, the best plan is to pick the nuts before they are dead or dry ripe. The pickers very soon learn to distinguish the ripe from the unripe nuts by the sound which is made when the nuts are tapped with the finger nail. If the nut is unripe there is still a large quantity of water remaining in the husk, and this emits a dull sound when it is tapped. As the fruit ripens, however, this moisture is withdrawn, leaving the husk dry. If this is tapped it emits a clear hollow sound.

If there is any doubt in the matter it is much better to pick the nuts before, rather than after, they are dead ripe. As has already been mentioned, in a moist atmosphere nuts are very liable to germinate on the tree, and if this happens all possibility of making first class copra from the crop is lost. When germination has started very active enzymes are formed which break down and soften the inner surface of the meat. In this condition the copra obtained is very difficult to dry and never has a good colour. It is moreover much more liable to become mouldy after it has been made. In India such nuts are always separated from those which are intended for the first grades of copra as they are liable to spoil the sample.

Thus it is much better to err on the side of harvesting nuts when they are under rather than over ripe. A nut which is under ripe certainly contains more water, and may therefore take a little longer to dry when making copra, but perfectly good copra can be made from it. It is often stated that copra made from nuts which are not dead ripe does not contain as much oil as that made from nuts which are dead ripe. This, however, is not the case. In fact the nut contains a greater percentage of oil to dry kernel before it is ripe than after, and if properly dried the copra should be richer in oil rather than poorer, when made from nuts which are not quite mature. Most of the copra which is exported from Cochin is made from nuts which are harvested before the husks are dead ripe, and this is classed as the best copra in the world. The reason why it is harvested then is that the husks of the nut give a much superior fibre if these are still green when harvested, and the coir industry is of the greatest importance to the coconut industry of Southern India.

The following table is of interest in showing the oil content of the nut at different stages of maturity. Two regular bearing trees were selected and three nuts were taken from each of the last six bunches on the tree. These are arranged according to their age, the oldest being placed first and ready for harvest. The figures are the average of three nuts from each bunch. It will be noticed that the size of the nuts as seen by their weight varies greatly. This is due to a great extent to the number of nuts on the bunch, and this number is shown in brackets in the first column.

TREE No. I, 109.

No. of bunch	Weight of whole nut without husk grm. Average	Weight of milk grm. Average	Weight of shell grm. (undried) Average	Weight of kernel grm. (undried) Average	Percentage of kernel in whole nut (without husk)	Percentage of kernel to whole nut minus milk
1 (16)	562	88·7	162·7	311·0	55·3	65·6
2 (12)	715	148·3	192·0	375·0	52·5	66·1
3 (14)	565	117·7	164·7	283·0	50·1	63·2
4 (15)	536	107·7	151·0	277·0	51·8	64·7
5 (17)	498	132·0	139·0	227·3	45·6	62·0
6 (11)	529	170·3	144·7	214·0	40·4	59·7

No. of bunch	Weight of kernel grm. (undried) Average	Percentage of moisture in kernel	Total moisture in kernel grm. Average	Weight of dry kernel grm. Average	Percentage of oil in dry kernel	Weight of oil in kernel grm. Average
1 (16)	311·0	44·87	139·4	171·6	59·44	102·47
2 (12)	375·0	47·75	179·1	195·9	59·21	116·03
3 (14)	283·0	49·28	139·5	143·5	62·71	90·01
4 (15)	277·0	56·74	157·3	119·7	62·54	75·27
5 (17)	227·3	59·54	135·6	91·7	56·49	51·81
6 (11)	214·0	64·55	137·7	76·3	57·88	44·46

TREE No. I, 168.

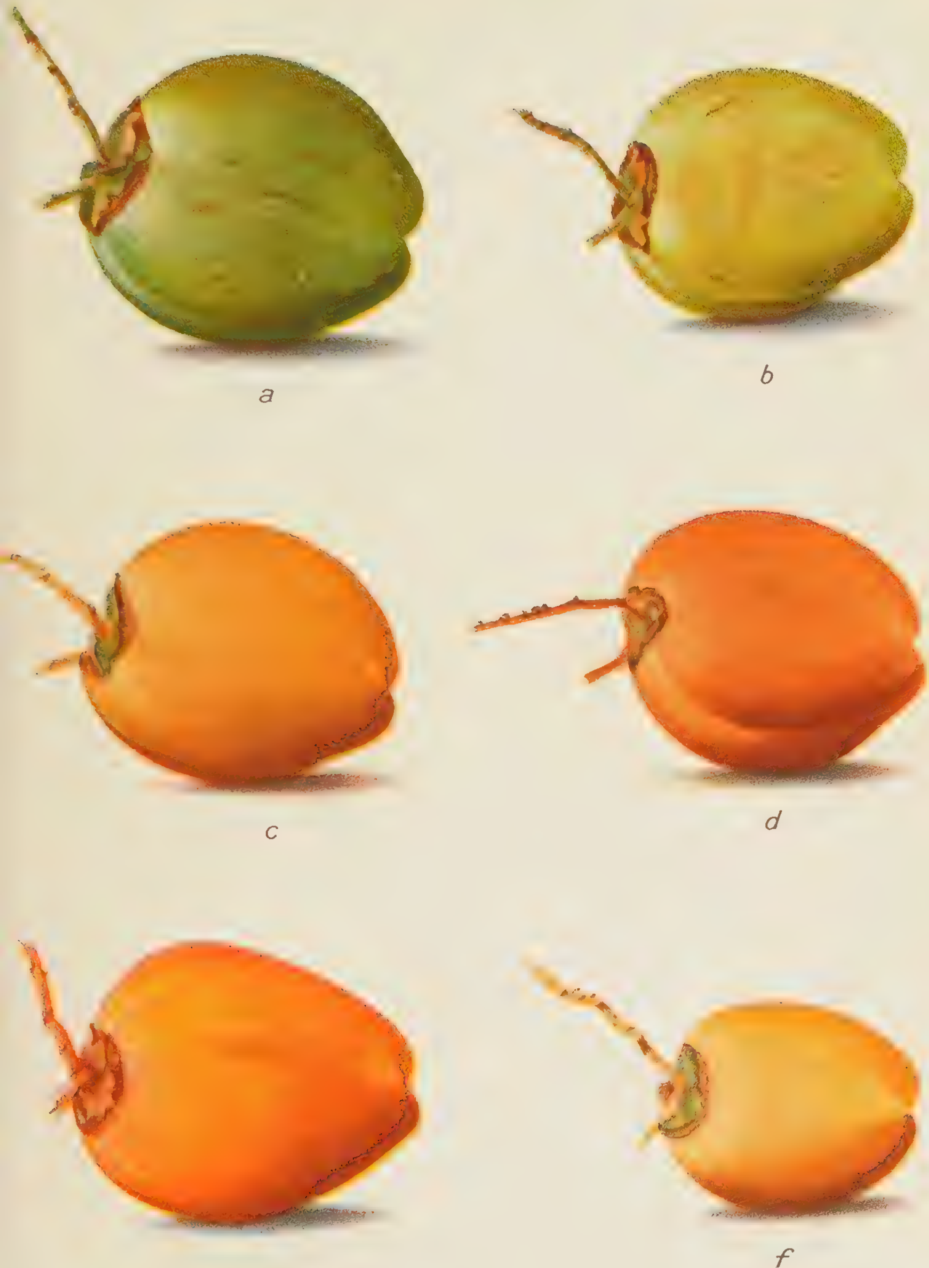
No. ot bunch	Weight of whole nut without husk grm. Average	Weight of milk grm. Average	Weight of shell grm. (undried) Average	Weight of kernel grm. (undried) Average	Percentage of kernel in whole nut (without husk)	Percentage of kernel to whole nut minus milk
1 (18)	440	38·0	128·3	274·0	62·5	68·1
2 (20)	488	70·3	133·3	284·3	58·4	68·1
3 (14)	467	85·0	135·0	247·3	53·0	64·7
4 (12)	486	83·7	138·3	264·0	54·6	62·4
5 (9)	416	71·0	117·7	227·3	54·7	65·9
6 (7)	476	118·3	126·7	230·7	48·5	64·6

No of bunch	Weight of kernel grm. (undried) Average	Percentage of moisture in kernel	Total moisture in kernel grm. Average	Weight of dry kernel grm. Average	Percentage of oil in dry kernel	Weight of oil in kernel grm. Average
1 (18)	274·0	45·61	124·8	149·2	56·04	83.79
2 (20)	284·3	44·53	126·6	157·7	60·96	96·17
3 (14)	247·3	48·18	119·3	128·1	57·53	73·66
4 (12)	264·0	48·58	127·8	136·2	62·97	86·70
5 (9)	227·3	48·37	107·6	119·7	68·68	82·38
6 (7)	230·7	62·07	142·8	87·8	51·52	45·49

These figures show clearly that as far as the oil content of the copra is concerned, the nuts complete the formation of oil some considerable time before the nut is ripe, and that the later process of ripening is probably in the formation of cellulose to strengthen the cell walls of the oil-bearing cells in the meat. Although not brought out in the figures given above, there is clear evidence in the analysis of individual nuts from the same bunch that the largest nuts on the bunch mature much more rapidly than the smaller ones and that they also contain a higher percentage of oil. The figures given also indicate that there is considerable variation from tree to tree in the rate of the formation of oil. Comment may be made that the percentage of oil in these figures is very low. This is the case. The samples were taken during the monsoon when the percentage of oil in the ripe nut is at its lowest.

The fruit of the coconut is what is termed a fibrous drupe. There is a large stone in the centre, which is the coconut of commerce, and this is surrounded by a well developed fruit coat, which in the young fruit is hard and fibrous though it can easily be cut with a knife. The outside has a smooth fibrous skin, which in the ripe fruit turns a grey-brown colour, but which in the young fruit and until the fruit is fully developed varies in colour with the general colouring of the parent tree. It may be a bright red, a pale yellow, a pale green, a red brown, a brown green and a dark green (Plate XIX). The last three (a, c, and d) are the usual colours of the ordinary coconuts from which copra is prepared. The flesh of the fruit coat is usually very astringent in the young fruit, but there are varieties where this is said to be edible. It has then an insipid sweet taste somewhat resembling the swede turnip. The thickness of the fruit coat is very variable and may be anything from a quarter of an inch to 2 inches. It may be that this thickness of the husk may form some guide to the original home of the coconut, those with a thick husk being much more likely to withstand a long sea voyage in the open sea than those

PLATE XIX.



Colour variation of the coconut fruit.

John Bale, Sons & Danielsson, Ltd

less well protected. Thus in the varieties of coconuts figured by Prudholme, it will be noticed that those obtained from the East Coast of Africa have a very much thicker fruit coat than many of the other varieties originating in countries where they are more nearly adjacent to other land.

Within this fibrous covering is the nut. This consists of a hard shell, which encloses the seed or kernel. Between the meat or fleshy part of the kernel and the shell is the seed coat, which is firmly attached to the meat. The meat in the ordinary copra varieties is half an inch thick, but in some of the ornamental varieties it is very much thinner. This thickness of half an inch is practically constant. Occasionally one sees a nut where the thickness is up to five-eighths of an inch, but such are rare.

Within the meat is a cavity which in the unripe fruit is entirely filled with liquid, but as the fruit ripens the quantity is reduced and it is only partially filled. This liquid is absorbed by the nut if it is stored, and it is stated that if there is no liquid left in the nut it will not germinate.

The shell of the nut has three ridges on the outside, which correspond to the division of the three carpels in the flower. At the end of the nut where this is attached to the fruit stalk there are three "eyes," one in each carpel. Normally two of these "eyes" are quite hard and the third is a "soft eye." It is immediately under this "soft eye" that the germ or embryo is situated, and when the nut germinates the young seedling forces its way through here.

In cross section the fruit is more or less triangular, and, as one would expect, the ridges on the nut alternate with the angles on the fruit (Frontispiece). If the fruit be examined, it will be found that one side is narrower than the other two If the nut be examined it will be found that one segment has a wider angle than the other two and that the centre of this widest segment is opposite the angle formed by the two widest faces of the fruit. It is this widest segment which has the "soft" or germinating eye. It is thus always possible to locate the position of the germinating eye by examining the outside of the fruit, and this is of importance in setting out the nuts in the nursery, as it is then always possible to place the nuts so that the germinating eye is uppermost. The germinating eye can always be recognized on the nut as it is bigger than the other two. The fibre over this also is softer and more open than elsewhere.

The meat of the nut is entirely composed of long thin-walled cells which are filled with oil. These radiate from the inside of the kernel to the rind.

The fruit of the coconut furnishes two commodities well known to commerce. The husk furnishes the fibre from which coir is manufactured, and the meat of the nut when dried furnishes copra. If the meat is grated and dried it furnishes what is known as desiccated coconut. Coconut oil is prepared either from the fresh meat of the nut or else from the dried meat or copra.

Coconut oil is a clear colourless oil. In the Tropics this remains as a liquid, but when brought to the temperate regions it becomes solid, forming a white fat. This oil is now one of the main ingredients of butter substitutes such as margarine. Inferior qualities of oil are often used for soap making.

The oilcake or "poonac" which is the residue after the oil has been expressed from the copra, is a valuable feeding stuff for livestock and is chiefly used for milch cattle.

THE GERMINATION OF THE SEED AND THE DEVELOPMENT OF THE SEEDLING.

The embryo, which is situated immediately under the soft eye, is enveloped in the meat or endosperm (Plate XX, fig. 3). If the ripe mature nut is kept moist it will commence to germinate. The germ commences to grow in two directions—the plumule or shoot grows towards the soft eye, and the other end of the germ develops an absorbent growth or haustorium, which grows towards the central cavity of the seed. Some very active enzymes are formed in this haustorium, which act on and break down the meat wherever it comes in contact with it. This enzyme appears to act on the cellulose of the cell walls of the oil-containing cells in the meat as there is always a quantity of free oil to be found in the "milk" within the cavity of the germinating seed. At the same time it also acts on the oil itself and converts this into sugar, which is absorbed by the haustorium for the use and development of the embryo.

As the germination progresses the shoot or plumule presses against the soft eye and, so to speak, forces the lid off. The pressure is not taken by the point of the plumule but by the hard horny surface of the lowest scale leaf formed. The haustorium also grows and commences to swell within the central cavity, forming what is commonly known as the "apple," and when this is full grown, it completely fills up the central cavity. Its surface is very finely corrugated, thus exposing a very large absorptive area. Wherever this "apple" touches the meat it turns this into a soft gelatinous substance. In colour this "apple" is a pale but bright yellow. In structure it consists of loosely connected thin-walled cells with large interspaces between them. Through it run long branching strands which form a vascular system conveying food from the "apple" to the young plant. These strands all converge to the soft eye, through which they pass to the young plant. Their combined strength in passing through this opening prevents any sudden jar given to the shoot from breaking the attachment to the food supply within the "apple."

The shoot, having made its way through the eye, commences to develop rapidly. At first it meets with little resistance from the fibre of the husk, as that which forms the "beard" round where the eyes are situated is made of soft short fibres. The apex of the shoot is still protected and is enclosed in hard horny scale leaves, the last one developed forming a sharp point with which, as the shoot grows, it forces its way through the coarser and tougher fibre of the fruit coat till finally it emerges through the rind of the husk. The shoot when it breaks through the husk resembles and is aptly described by the Tamil as the "crow's beak."

About six weeks after germination has commenced the first root is formed. This is produced from the axil of one of the basal scale leaves of the young plant. Within two or three months of this, this root will be from 4 to 5 inches in length and will have formed numerous branch rootlets which ramify through the fibrous husk. This husk is very rich in plant food, especially in potash, which is required in large quantities by the rapidly growing embryo. Thus the young plant has a double source of food supply. That supplied by the "apple" from the meat of the nut, and that supplied by the root system which is ramifying through the husk.

Other main roots are formed from time to time, but always at one side or the other of the first root formed. There is, however, great variation in the rate at which these are formed, though there are usually three or four by the time that the apex of the shoot has penetrated to the outside of the husk.

When the shoot has emerged through the husk, it then commences to form green leaves. The first one to be formed is very small and is merely the continuation of the end of a scale leaf. After this each consecutive leaf is larger than the previous one. The leaf of the seedling is entire and forms two wings one on each side of the midrib. The end of the midrib terminates in a long fibrous thread.

The work of the "apple" has to proceed much more quickly than the young plant can utilize the food stored by it. This is necessary since it has to dispose of the oil, which, though evidently there is some strong preserving agent produced, is liable to go bad. Though the food is absorbed in the form of sugar, it is stored up within the "apple" in the form of starch grains, presumably till it is required by the young plant.

How great is the preserving force of the enzymes formed by the "apple" can be realized when it is stated that the

PLATE XXa.

FIG. 1.

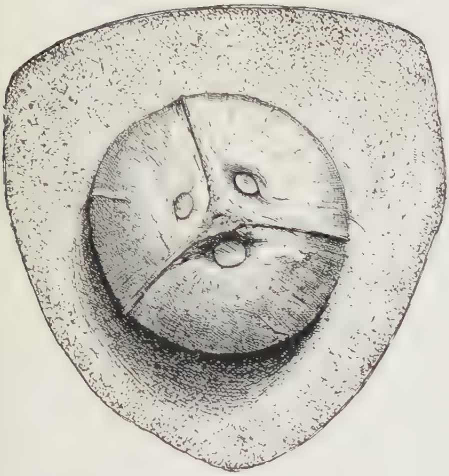
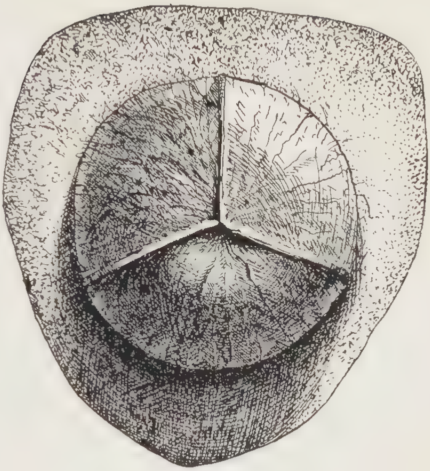


FIG. 2.



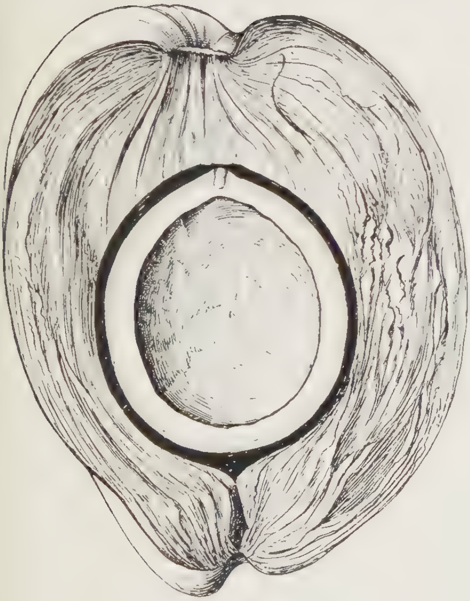


FIG. 3.

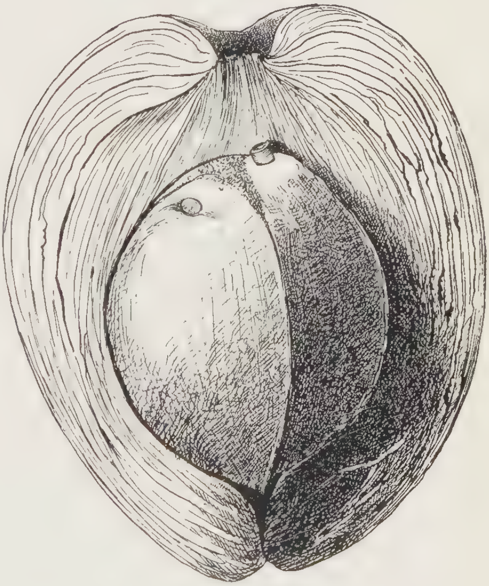


FIG. 4.

The germination of the coconut.

gs. 1 to 3.—Different views of the ripe nut. Fig. 4.—One month after germination has commenced.

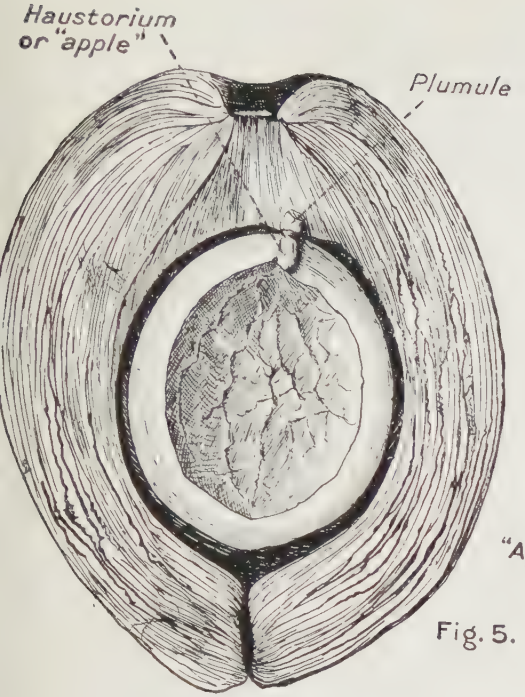


Fig. 5.

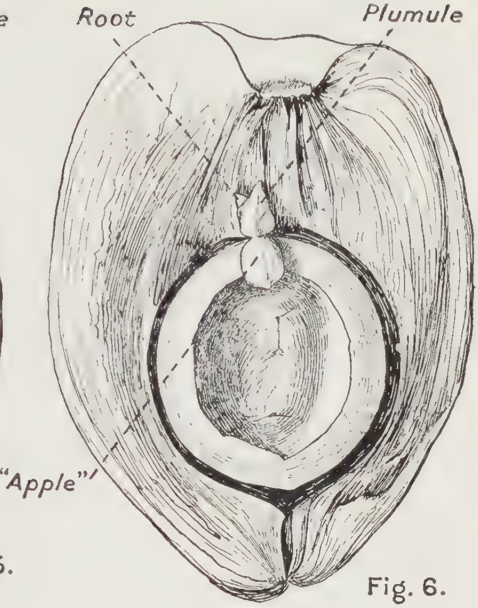


Fig. 6.

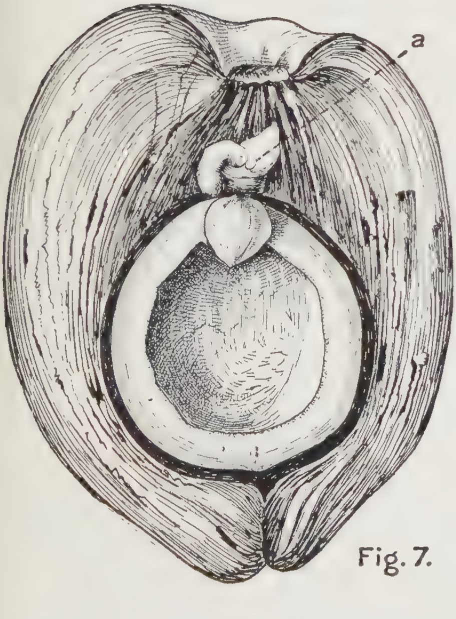


Fig. 7.

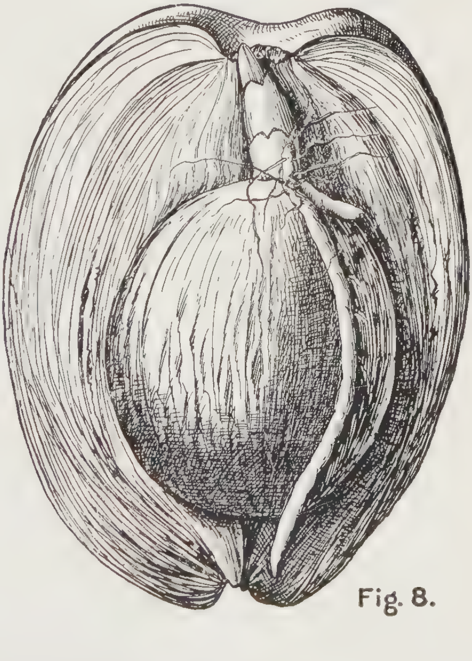


Fig. 8.

The germination of the coconut.

Fig. 5.—One month after germination has commenced. Fig. 6.—Two months after germination has commenced. Fig. 7.—Three months after germination has commenced: (*a*) the scar on the lowest scale leaf where this forced its way through the "soft eye." Fig. 8.—Four months after germination has commenced.

"apple" has been found to be quite sound after two years, although all the meat had not been absorbed. This does not say that the meat will always be present at this age, as the length that it will last will depend on the rate at which the seedling develops. Usually the "apple" will be full-sized at the end of one year, and all except a small portion of the meat left at the end furthest away from the germ will be absorbed. At this stage the outside of the "apple" will have taken on a greenish colour.

In some countries nuts are germinated on purpose to produce this "apple" which is considered a delicacy. It very much resembles sponge cake, only it has a slight coco-nut flavour. The younger "apple" is very much sweeter than the older one.

Plate XX A to F illustrate clearly the development of the young plant and require little explanation.

Figs. 1 and 2 illustrate the ripe nut where the husk has been cut in two crossways. The germinating or "soft eye" is the lowest one in the figure and is situated in the angle of the largest segment. The side of the fruit or husk opposite this is the shortest of the three sides. The largest segment which contains the germinating eye can be easily identified in fig. 2.

Fig. 3 represents a ripe nut cut in two lengthways and shows the position of the embryo underneath the thin shell of the soft eye.

Figs. 4 and 5 illustrate the development of the germ one month after germination has commenced. Fig. 4 shows the plumule when it has just emerged through the "eye" with the thin piece of shell lying on the top of it. Fig. 5 illustrates the fruit cut lengthways and shows the shoot or plumule (*a*) outside the nut, and the haustorium or "apple" (*b*) starting to grow within the meat.

Fig. 6 illustrates the development two months after germination has commenced: (*a*) represents the shoot; (*b*) represents the "apple;" and (*c*) represents the first root formed.

Fig. 7 illustrates the development of the seedling three months after germination has commenced: (*a*) is the scar left on the first scale leaf where this forced its way through the soft eye.

Figs. 8, 9 and 10 illustrate the development of the seedling four months after germination has commenced. Fig. 8 shows how the first root has grown and how thin fibrous branch roots have grown from this into the husk. A second root has emerged beside the first one formed. Fig. 9 represents the same cut in two lengthways and shows how the "apple" has developed within the hollow of the kernel. Fig. 10 is a longitudinal section through the plumule and the "apple," and shows the fibrous strands all converging to the soft eye and from there into the plumule.

Figs. 11 and 12 illustrate the development at the age of five months. Here the "apple" has almost completely filled up the cavity of the nut and has consumed a considerable portion of the meat, especially towards the germ end where it has been in contact with the meat for some time.

Figs. 13 and 14 represent the young plant when six months old.

PLATE XXc.

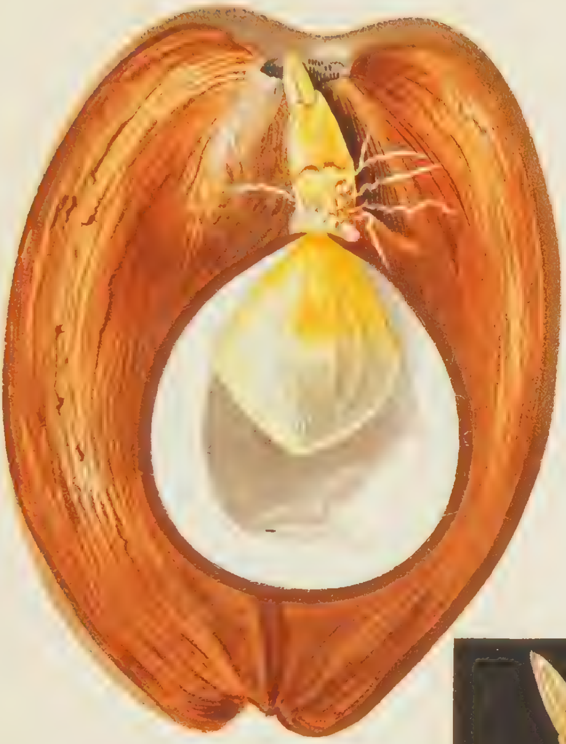


Fig. 9.

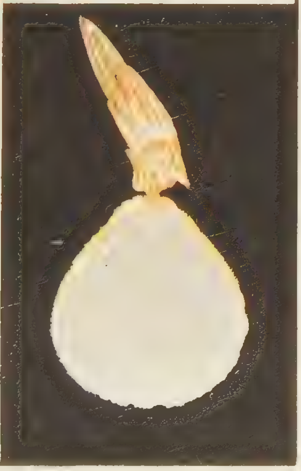
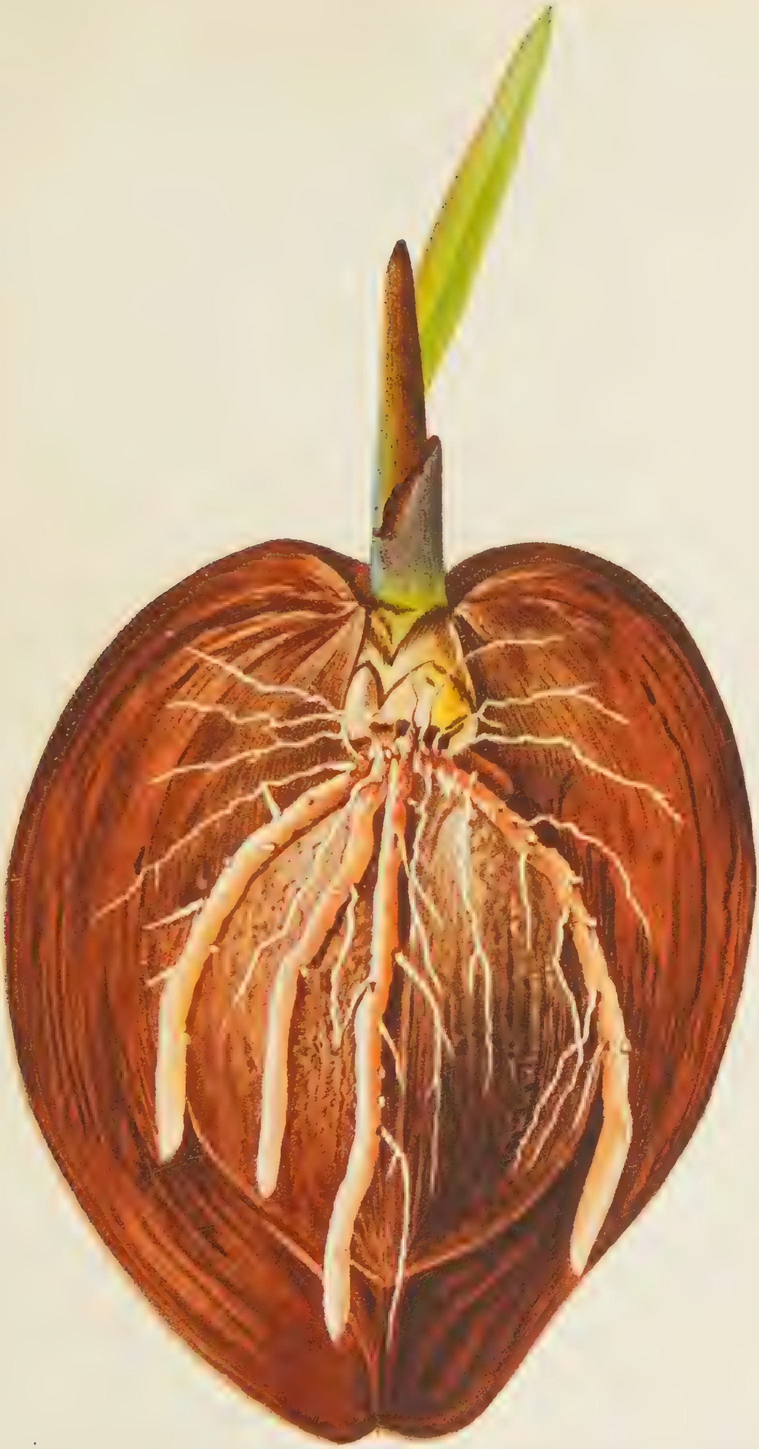


Fig. 10.

The germination of the coconut.
Fig. 9.—Four months after germination has commenced. Fig. 10.—Longitudinal section through the "apple" and the plumule.



Germination of the coconut.

Fig. 11.—Five months after germination has commenced. Note the fibrous branching roots which ramify through the husk.

PLATE XXE.

FIG. 12.

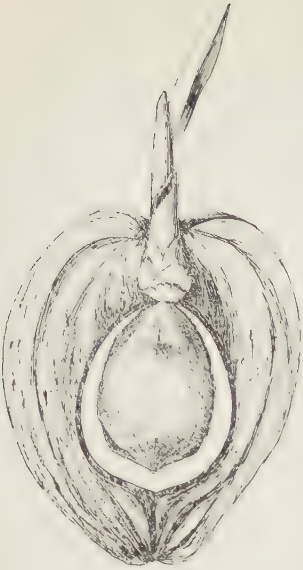
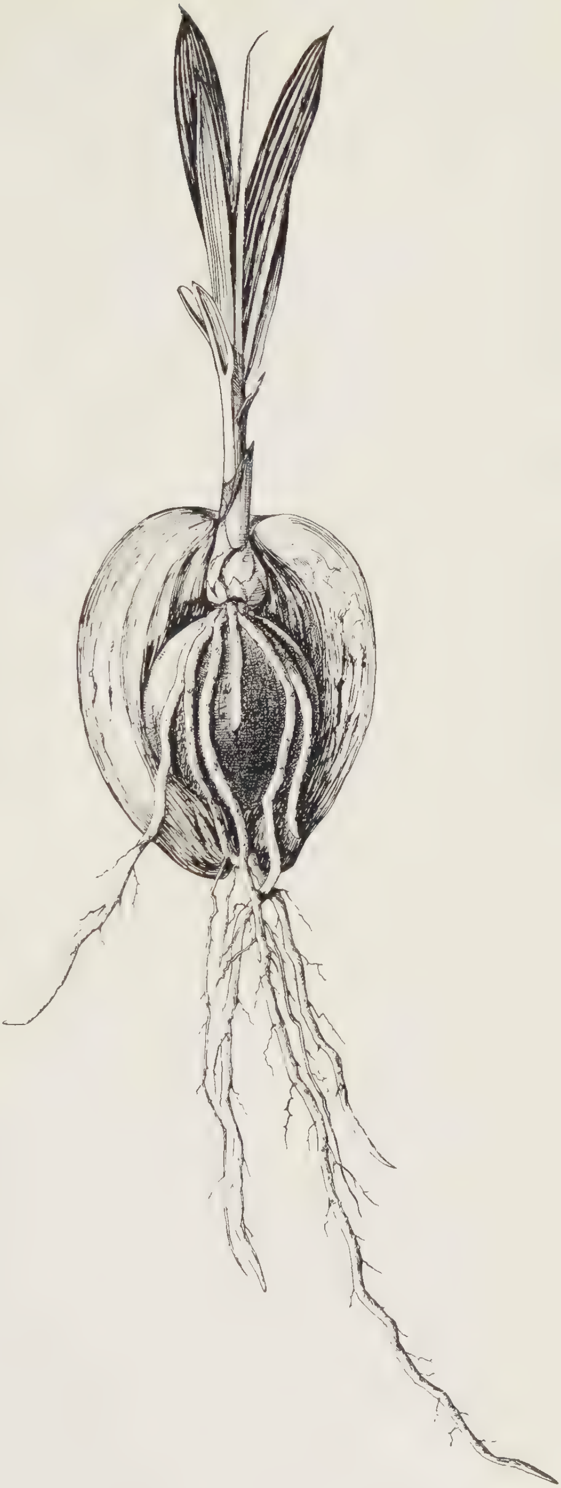


FIG. 13.



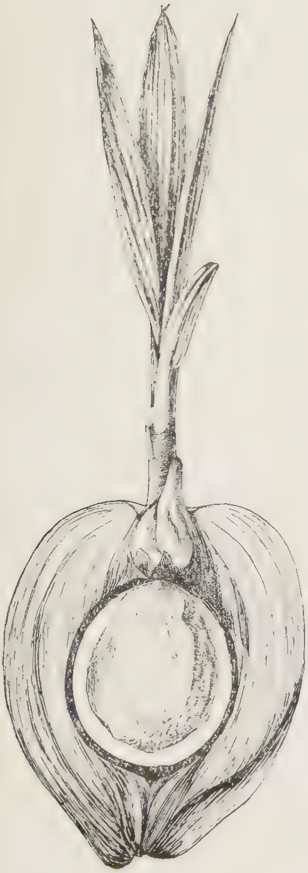


FIG. 14.

Germination of the coconut.

Fig. 12.—Five months after germination has commenced. Figs. 13 and 14.—Six months after germination has commenced.

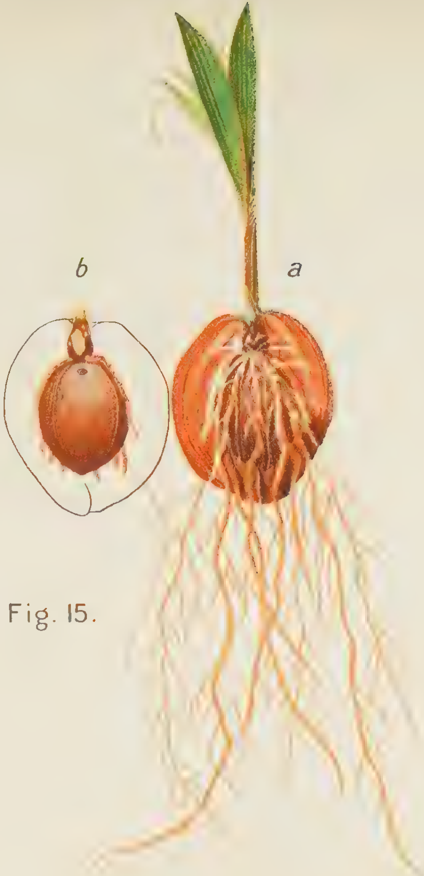


Fig. 15.

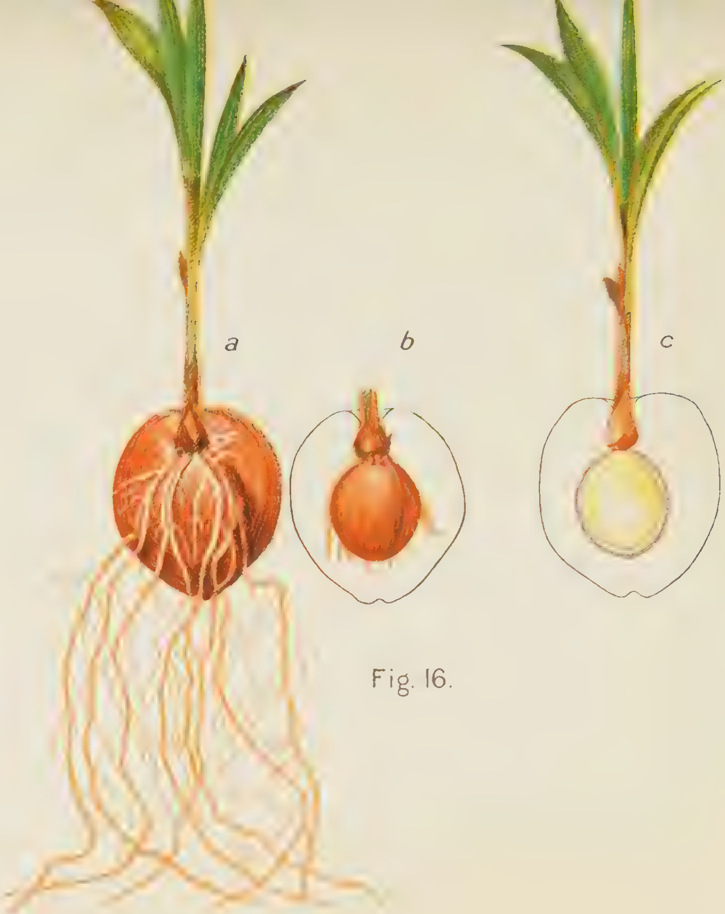


Fig. 16.

Germination of the coconut.

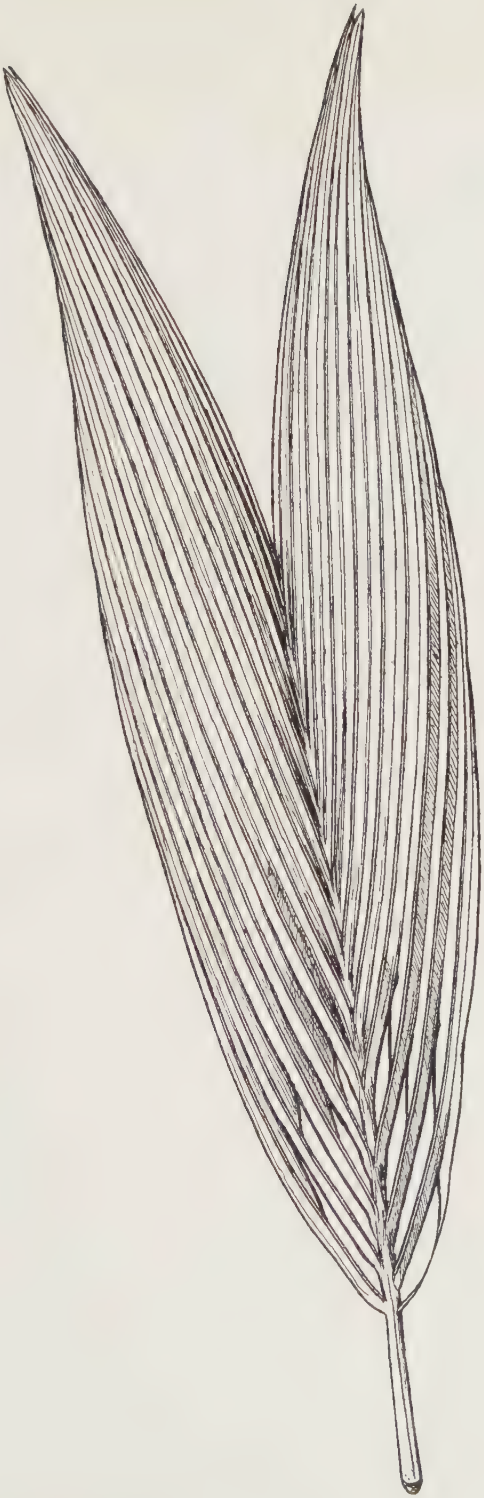
Fig. 15.—Eight months after germination has commenced; (*b*) is the reverse side of (*a*). Fig. 16.—Nine months after germination has commenced; (*b*) is the reverse side of (*a*). Note the young roots just emerging. (*c*) Note how the "apple" has consumed the "meat."

Figs. 15 and 16 represent the young plant at eight and nine months old respectively. It is to be noted here how all the roots formed are given off at one side or other of the first root formed. The reverse side of the germinating nut shows that the roots have only half encircled the base of the young shoot. The apple has used up a large portion of the meat.

The rate of the development of the seedling after it has once commenced to form green leaves is largely dependent on the fertility of the soil, and what may be a normal two year old tree in one country would represent four to five years' growth in another where the soil is less fertile.

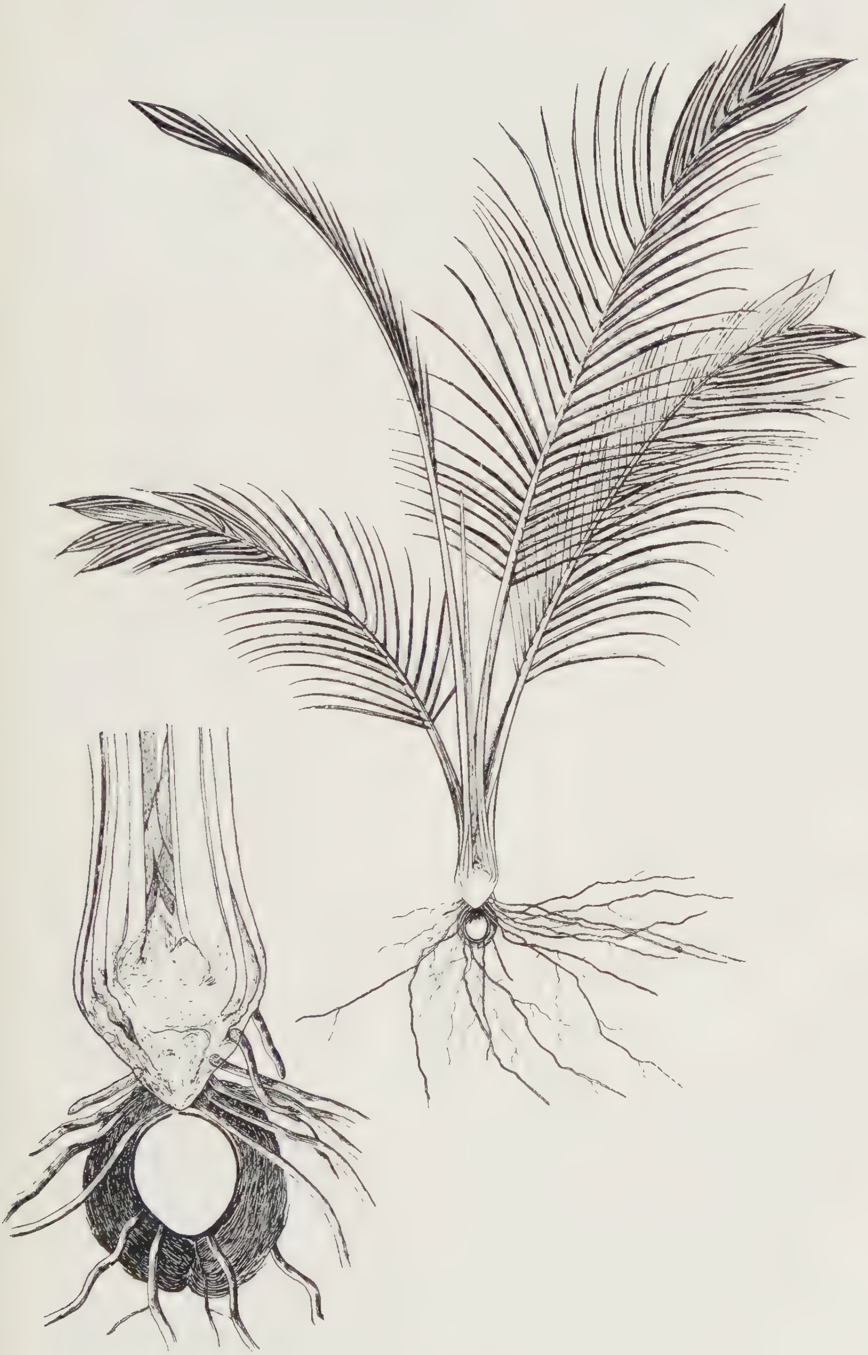
After the tree has formed some eight to ten leaves it will commence to produce leaves which tend to split into leaflets. The first tendency in this direction is seen at the base of the leaf, where splitting commences between the parallel veins of the leaf (Plate XXI). At first these do not split more than half way up, but in the next leaf there will probably be several separate leaflets at the base. This process will go on till the leaves which are formed are composed entirely of split leaflets. The leaves have not, however, even at this stage reached their normal maximum size and they will not do so till the base of the future tree has fully expanded to its maximum girth and the upward growth of the stem has commenced. This may be anything from three to ten years after the seedling has been transplanted.

After some twenty leaves have been formed in all, the young tree will commence to form a bole. This at first is a swollen base to cope with the development of larger and larger leaves and to form a support and a reserve for the rapidly growing bud or "cabbage." The formation of this "cabbage" may be described as the weaning of the tree. The reserve in the "apple" has been used up and it is necessary for the plant to form a new reserve of its own. The formation of this reserve should be looked for when young trees have to be moved; for either they must be moved before the reserve in the "apple" is exhausted, or one must wait till the new reserve has been built up and established in the "cabbage" or bud. Plate XXII represents the stage in the young plant when the reserve in the nut is exhausted and a fresh reserve has been built up in the "cabbage" or bud.



Leaf of the coconut seedling commencing to split.

PLATE XXII.



Section through a young coconut tree which has been "weaned," showing the development of the "cabbage."

PART II.

PLANTATION MANAGEMENT.

THE SELECTION OF A SITE FOR A PLANTATION.

The coconut palm, though essentially belonging to the moister regions of the tropics, is one of the most adaptable of plants. Here lies its strength as well as its weakness, and this adaptability may lead to its being planted on land which is entirely unsuited to it as a permanent crop. This may lead, not only to great disappointment and financial loss and a hesitancy to invest capital in such undertakings, but it brings in its wake diseases and pests which are a menace to other healthy crops in the vicinity.

One of the first points to be considered in selecting land for a plantation is the question of drainage. A glance at Plate III, fig. 1 will emphasize the necessity for this. The word drainage is used in a wider sense than is usual in temperate agriculture. Drainage in the tropics refers to free water movement in and through the soil and consequent soil aeration. For example, rice land which may be kept under water for months on end, may be well or badly drained. A well drained soil in this case is one where there is constant soil water movement through the soil, and this movement may be lateral or vertical. A badly drained soil is one where this soil water movement is lacking. Coconuts will thrive admirably on the margins of well drained rice fields and they will also thrive close to the water's edge on a sandy sea beach, as this is influenced by the ebb and flow of the tide. Similarly along the banks of backwaters, lagoons and estuaries, where there is tidal action and where the soil texture admits of free water movement, coconuts will do well.

Even where drainage is absent and the stagnant water level is near the surface the coconut will often appear to thrive for some time. A reference to Plate II which shows the spread of the root system of the young plant will explain this; and on such land, if very rich, the trees may have the appearance of great promise. But the time will come when the tree is unable to maintain itself on the shallow root system which it has been forced to produce, and it then becomes unhealthy and incapable of producing a crop of nuts. The only possibility then of making the trees produce is the costly and temporary one of manuring. The writer recalls seeing a plantation where the soil was, to all appearances, a coast sandy soil. The trees were well grown but were an unhealthy colour, and there was no sign of any nuts. On examining the soil it was found that the water table was little more than 2 feet below the surface. The trees had made many attempts to send their roots down into the water, which on analysis was found to be impregnated with magnesium salts, but these roots were either dead or dying. Another somewhat similar case was that of a native plantation situated close to the mouth of a river. Here the soil had been raised in parallel strips to make the cultivation of coconuts possible, yet within one month of the cessation of the monsoon and though the soil was saturated with water within a few inches of the surface, the owner had already commenced to water the trees in order to keep them alive. Most of them were suffering from bleeding disease, which was evidently aggravated by the lack of drainage.

One reads in books on the coconut of the danger of drought affecting the yield of the trees—and this in countries where never a month passes without some rain. This is really a case of insufficient drainage and the planting of the crop under unsuitable conditions. On the Malabar coast of Southern India the heaviest crops of nuts are harvested in the months of May, June and July at the end of seven months dry weather. The coconut, if given good drainage, is one of the most drought-resisting of trees, and the reason for this is not far to seek when the root system is examined.

The essentials for natural drainage, therefore, are a free working soil of open texture, and either a deep water table or else free water movement through the soil. Too often, in newly opened-up countries, has the coconut had to take a back seat and give preference to rubber, which has been given the pick of the best-drained land, while any low-lying land which is not considered good enough for rubber has been relegated to the coconut. The result is that in those countries the possibilities of the coconut as a revenue producing crop have very rarely been realized.

The natural drainage of the soil is, therefore, the first desideratum in choosing a site for a plantation. An examination of the natural vegetation on the land will often afford a useful guide to this. In open country, the presence of rushes, sedges and other water-loving plants will indicate poor natural drainage. Where there is forest growth the same method holds good, but it must not be forgotten that a dense forest growth makes great demands on the water in the soil, and that, though the land may appear to be fairly dry when covered with forest growth, when the trees have been removed the drainage may be far from what is desired. The writer remembers seeing a native clearing on low-lying land near the coast where most of the forest trees had been removed. Those trees which had been left were all dying for no other apparent reason than that they were unable to withstand the excess of water in the soil after the main part of the forest had been cleared. Many trees are very sensitive to drainage, and a knowledge of their likes and dislikes in this respect may be of considerable value when examining land for the purpose of a plantation. As an example of this the writer recently visited the famous teak plantations at Nilambur in South India. These plantations were very carefully planted between about 1845 and 1860. The present working plan of these forests is to all intents and purposes a soil map of the locality. All the first class forest is confined to the alluvial land along the banks of the river, except where these are too low-lying to admit of adequate drainage. Where the alluvium merges into laterite soil, the forests are all classed as second class, while the third class forest is on the pure laterite, or on the low-lying land along the immediate river banks where the drainage is bad. On the laterite, much of the teak has been killed out by the natural regeneration of *Xylia dolabriformis* which thrives best on laterite soils, while on the low-lying and badly-drained land it has been replaced by the natural regeneration of rose-wood.

In forest land where drainage is deficient one must also look out for the excessive formation of humus or organic matter. On such land this will often accumulate and cause the formation of what resembles peat. Usually where this occurs there will be found underneath an impermeable layer of stiff clay. An examination of any water courses in the neighbourhood will often form a guide to the nature of the sub-soil.

In the tropics one often comes across alkaline soil formations. Though these usually occur in regions which are too dry for the proper growth of the coconut, they do occur at times where there is a heavy rainfall. The nature of the herbage on the ground surface will usually indicate the presence of such areas. The surface soil also will be dry and powdery when the weather is dry and will become a swamp after there has been heavy rain. On digging into such soil, one will usually find an alkaline soil layer or salt pan at anything from 1 to 3 feet below the surface. This pan is always very impervious to water and frequently beneath it will be found fresh water which is held down by the pan.

Provided the natural drainage is sufficiently good, the level lands near the coast are probably the best suited to coconuts. Not only are plantations easier to manage, but the cost of transit and of extracting the crop is reduced to a minimum. There is, however, no objection to undulating land provided it is not too steep. The great danger on undulating land is soil denudation, which may be very considerable with a tropical rainfall unless steps are taken to prevent it. The root system of the coconut is such that it will not stand too great surface soil denudation. There is no tap root. All the main roots are the same size and are merely anchor roots, which hold the base of the stem upright. There is no development of thick roots which in the case of an ordinary tree can often support the stem although the soil has been washed away from the base of the bole. Further the bole of the coconut is unable to increase in girth, whereas in the case of an ordinary tree the increase in girth, not only of the stem but of the main roots, forces soil up round the base of the tree.

A free working soil of considerable depth and with good drainage, even though of poor average fertility, is much more desirable than a rich soil which has not got free drainage, either being too heavy or with too high a water table. It may take longer to bring the trees to bearing, but the future prosperity of the plantation is assured when once it does commence to bear. The root system of the coconut has a very wide feeding range, and with good drainage will go to considerable depths. With trees planted 30 feet apart, there are fifty-six to the acre. Thus each tree has on an average 777 cubic feet of soil for the roots to range in for each foot depth of soil. Thus where the roots can go down to say 8 feet, the tree has four times the quantity of soil which one has which can send its roots down only 2 feet.

Other considerations are of purely local significance, but at the same time should receive consideration when selecting land; such as labour supply, communications, easy reach of markets, healthiness of the locality, which will often affect the labour supply, as this is shy of going to a locality which has a notoriety for fever and malaria.

As regards soils, therefore, stiff clay should invariably be rejected. So also any land which has a stiff clay subsoil. Peaty soils should be rejected, unless there is a large admixture of sand. Such mixed peaty soils are, however, seldom of any extent and are usually formed near the coast where the sea has receded and there has been a wash of peat down to the sea. Even here the subsoil should be looked at very carefully to see that it is not a heavy clay. Peaty soils are always very rich in plant food and the early growth of coconuts is usually excellent, but a plantation on such land will always give trouble and will soon cease to be profitable. The clearing of such land, which is usually high forest, exposes this peat to the weathering action of the air and it quickly disappears. It has been stated that in the Tropics such soils disappear at the rate of 6 inches a year. The result of this is that the trees have a very poor root hold and if they do not lie down of their own accord will do so if there is anything of a wind storm after they have once got their heads well above ground. When the peat has finally disappeared, what trees are left will be resting right on the heavy clay which is almost invariably found to underlie this peat. There is no objection to gravelly soils. Soil aeration in such case is great and the roots of the coconut will have a wide range in which to search for plant food. This will counterbalance the natural poverty of the soil, which is to be expected where there is a heavy rainfall.

Soils of laterite origin can often be profitably planted provided the solid rock does not come too close to the surface. Such soils invariably have excellent drainage. In South India where the stress of population on the land is great, large areas of laterite hill sides have been planted within recent years. Sometimes the planting holes are cut out of the solid laterite rock, so keen is the competition for land for planting coconuts. In this latter case some 4 to 5 lb. of common salt are put in the bottom of the planting hole, which is said to have the effect of breaking down the laterite and thus allows the roots of the coconut to find their way through to the softer rock below.

Proximity to the sea is usually considered an essential to the coconut palm. Certainly the palm does seem to thrive better near the coast, but excepting that the nearness to the sea has a considerable effect on the climate as well as on the soil, there seems to be no hard and fast rule to this effect. A coastal climate is never so subject to great changes in temperature, while the humidity is always high. Hot dry winds are the exception on the coast and high temperatures only occur when a strong land wind is blowing. This is very different to an inland climate. Further than this there is a much larger area of rich alluvial soil near the coast than there is inland. Along the sea border also there is usually a strip of varying width of coast sandy soil where drainage and soil water movement are good. Very fine coconut gardens are, however, to be found several hundred miles from the sea in certain favoured localities. A wide valley bottom where there is alluvium as well as a deep water table will, provided it is sheltered from hot dry winds, produce excellent crops of coconuts. Many such fine coconut and arecanut gardens are to be found in the Salem district of Southern India, which is situated midway across the Peninsular and some two or three hundred miles from the sea.

The coconut thrives best at a mean temperature of about 85 to 95° F. without any great variation from this mean, and thus it thrives near the coast, where such atmospheric conditions are more likely to prevail. For this reason the tree will not thrive at any great elevation above sea level, and a plantation should be kept well below the 1,000 feet above sea level zone. There are cases where there are coconut plantations at higher levels than this, but they are not to be recommended as a financial undertaking. For example there are some fairly good gardens near Bangalore in Southern India, which are between 2,000 and 3,000 feet above sea level. The trees here are, however, more or less an acclimatized variety, for, if seed nuts are brought from the coast and grown here, the trees will very seldom fruit. Around Kandy, in Ceylon, there are plenty of coconut palms which bear fruit, but no one who intended making a commercial success of coconuts would ever dream of planting at this elevation which is somewhere about 1,700 feet above sea level.

SEED AND SEED SELECTION.

The question of seed supply is of the greatest importance. It must be remembered that the coconut crop is to remain on the ground for a period of not less than forty years, and in some cases may remain profitably for sixty years. It can readily be understood, therefore, that the matter of getting the right type of tree and trees of the best quality is of primary importance.

The variation in the development of the root system and the variation in the main direction which the roots take have already been referred to on page 3, where emphasis is laid on the importance of selecting seed nuts from trees grown on land with similar soil conditions to those which are to be planted up.

There is then the question of the selection of the trees on such land from which seed nuts are to be taken. A detailed cropping register of each tree is of course the ideal to work to, but it is doubtful if any such exists. The maintenance of such a register will be discussed later. A great deal, however, can be learnt from an examination of the trees.

In the first place the trees should be mature. They should not be less than twenty-five years of age, and should not be more than forty-five, or probably younger than this if the soil is very fertile. It is a generally accepted theory that seed should not be taken from young trees. These have not yet reached a stage when the question of the reproduction of the species is one of pressing importance to the tree, and the fruit which is formed is usually a good deal larger than the average. Again, when the tree is old, the fruit is very much smaller, and since the coconut is so very dependent on the reserve food stored up, not only in the seed, but also in the husk or fruit coat any great diminution in the size of the fruit is to be deprecated. Moreover, old trees are very tall, and it is difficult to examine these with the same thoroughness as trees which are not so tall. Only trees which are grown under ordinary field conditions should be selected. Those near dwellings and coolie lines and those near the margin of a plantation will frequently yield a larger crop than the average tree on account of being favoured with additional plant food either from the soil or the air.

An examination of the stem will show whether a tree is a regular and heavy cropper. When a tree has once commenced to bear fruit the rate of stem growth will in the case of a regular cropping tree be very much reduced (see Plate VII). The interspaces between consecutive leaf scars on the stem should therefore be very small. If the leaf scars are deep, in addition to being close together, then it may be taken for granted that the tree is not only a regular but also a heavy cropper. Stem growth is reduced to a minimum when a tree is bearing heavy and regular crops.

The conclusions drawn from an examination of the stem can be confirmed by an examination of the crown. On the same analogy, the crown should be compact, as this means that the leaves are very close together. A further point to be noted here is the number of leaves which are on the tree. Attention is invited to the arrangement of the leaves on the coconut tree described on p. 38. This is what is known as a two-fifths phyllotaxis, or in other words the leaves are arranged in five definite spirals. These spirals may be towards the left or the right according to the direction of growth in the individual tree, and this point must be observed in the case of the tree under examination. In order to estimate the number of leaves on a tree all that it is necessary to do is to count the number of leaves in one spiral and multiply the result by five. If there are seven leaves in a spiral then there are approximately thirty-five leaves on a tree. It will be found that the number of leaves on a tree will vary from about twenty-five to forty. Selection should be made of those trees which contain the highest number of leaves, and for two reasons. Firstly, the rate of leaf production will in such a case be greater, and, as has already been shown, the rate of leaf production in a regular bearing tree is the same as the rate of bunch production. Thus the number of bunches which will be formed in a given time will be greater. Secondly, the leaves are essential to the tree, as it is these which not only regulate the rate at which crude sap is taken in by the roots from the soil, but also by the action of sunlight on the leaf surface, cause the elaboration of the sap which comes from the roots to the leaf area. Here the carbohydrates manufactured from the carbonic acid in the air is incorporated with the sap which contains the mineral plant food taken in by the roots. The greater the number of leaves on a tree, therefore, the greater is the amount of work which the tree is capable of doing.

Another point which should be noted is the length and strength of the leaf stalk and also of the fruit branch stalk. A long slender leaf stalk should be avoided, and so also a long, slender fruit branch stalk, which seems to be a correlated character. A long slender leaf stalk cannot support the weight of a full bunch of nuts (Plate IX), and very often the bunch, which should be supported on the leaf stalk, slips off (Plate X), and when this happens the fruit branch stalk is very apt to buckle, which causes the nuts to fall before they are mature. This may not be the case in the tree actually under observation, but there is always the danger that it may happen in the case of its progeny. Plate XI is a good type of tree with short leaf and fruit branch stalks and shows how the bunch is supported on the leaf bracket.

Though a tree may be bearing regularly it does not follow that all the bunches carry approximately the same number of fruit. If this can be ascertained it is a most important point, but it can only be done with any accuracy if a detailed bearing register is maintained. Many trees though bearing regularly will produce much heavier bunches at one season than at another, and since this appears to be a seasonal factor (graph on p. 62), it not only means that a tree is apt to exhaust itself by too heavy cropping at one season, which it has to recuperate by light cropping at another, but it means that the work of harvesting is concentrated at one season of the year. Harvesting is no light work, and if it can be more evenly distributed throughout the year, the seasons being suitable, it will greatly ease the question of the distribution of labour. Whether it is the case in other countries or not the writer does not know, but in South India the heaviest cropping season coincides with the season when cultural work, not only on the estate, but also that connected with the agricultural operations of the people, is at its busiest. This makes it difficult at times to get labour when it is required.

As regards the shape of the seed nut, opinions seem to differ in different countries, and probably it is not a matter of any serious importance. On the Malabar coast the long nut is considered generally to be the best for copra, but in many other countries the round nut is preferred.

As regards the size of the nut, this varies for several reasons. Firstly, there is a variation according to kind. Some trees give a very much bigger nut than others, and since varieties largely go by a large number of the same type of tree being grown in the same locality, certain places are noted for their large-sized nuts. It does not necessarily mean, however, that such trees produce a heavier crop, as it is usually the case that such large nut varieties are shy croppers. The nuts are large, but the number of nuts per bunch is small. Secondly, there is the variation due to the number of nuts on a bunch. If the number is large, the individual nuts on the bunch are correspondingly small. Thirdly, there is the variation due to the fertility of the soil and to equable atmospheric conditions. In some countries only 4,000 nuts are required to give one ton of copra, while in others it takes as many as 7,000 to produce the same weight. Taken generally, the medium-sized nut is preferred. This is found to be a much more regular cropper, and on the whole gives a much better return of copra per tree than the large nut.

A certain amount of selection can be done in selecting the size of the nut rather than the size of the fruit. That is to say, in selecting those trees which carry nuts with a thin husk. The size of the fruit is often out of all proportion to the size of the nut within, and since the husk contains a large quantity of those plant foods which are just as essential to the growth of future crops of nuts, it is probable that selection for thinness of husk may lead to greater fruit production. Some may say that the husk is of importance since it is from this that coir is produced, but good quality coir requires a deal of hand labour which is more often than not a consideration on a coconut plantation, and can never be looked upon as the main industry of the coconut, which is copra or oil.

These are the main lines for selection which are possible when starting a new plantation, but they are anything but ideal. Anyone who contemplates supplying seed nuts or seedlings to intending planters of this crop should be able to do much more than this and would probably find it well worth his while. After all the cost of seed, though a considerable item, is nothing to the value of the established crop, and it would pay any one to invest double or treble the amount on seed if he is sure of getting the best available.

To develop a real seed business—and on a large estate, which it is intended to extend, or, if the plantation is old, which it is intended to underplant, every manager should have his own selected seed trees—a much more careful history of the parent trees is necessary. A preliminary selection should be made on the lines indicated above and a detailed bearing register should then be kept for each tree so that those which prove to be wrong selections can be eliminated. A register kept on the following lines where examples of two separate trees have been given will furnish much useful information about the bearing capabilities of individual trees, provided that harvesting is done at regular and stated intervals. Various symbols can be used to denote any information required. The following have been found useful :—

f = spathe in flower.
x = spathe without any female flowers.
: = barren leaf axil.
b = flower bud destroyed by rhinoceros beetle.
v = flower bud dried or undeveloped.

Each vertical column represents a leaf with its fruit bunch, and the thick line denotes the completion of a phyllotaxis. The number of fruit which set is usually the same as the number which ripen, but it is as well to note this, as it is then quite easy with this information to find one's place on a tree. This register shows at a glance the number of leaves, bunches and nuts formed on a tree within a definite period. It shows whether a tree is a regular bearer and whether the tree carries a heavy crop throughout the year or whether it bears heavier crops at some seasons than at others. The tree given in the first example produced fourteen bunches from April 16, 1919, to April 14, 1920, while that in the second example produced only ten bunches from November 30 till October 16 of the following year, as three

TREE NO. II, 194 (SPIRAL RIGHT).

Date :	15.1.18.	20.3.18.			9.5.18.			12.7.18.		9.11.18.	21.1.19.		16.4.19.			8.7.19.			29.9.19.			14.12.19.			14.2.20.		15.6.20.			13.8.20.
Number of female flowers	16	24	14	14	17	24	24	20	13	21	16	12	24	22	31	17	12	33	34	28	19	14	17	21	23	20	27	31	28	25
Date :	22.6.18.		9.11.18.			21.1.19	16.4.19.				8 7.19.		29.9 19				14.12.19.		14.2.20		15.4.20.			15.6.20.		13.8.20.	16.10.20.			15.12.20.
Number of fruit which set	8	3	4	2	2	14	8	9	8	4	8	6	9	10	12	8	10	11	4	8	4	8	4	8	6	9	12	14	7	5
Date :	16.4.19.	31.5.19.			8.7.19.		23.9.19.		14.12.19.		14.2.20.		15.4.20.			15.6.20.		13.8.20.			16.10.20.									
Number of nuts harvested	8	3	4	2	2	14	8	9	5	4	8	5	8	10	12	8	9	1	2	8	4									
Number of barren nuts	...		...		...			...	...			1		...		...		6	1											

TREE NO. VIII, 141 (SPIRAL LEFT).

Date :	18.1.18.				30.3.18.		11.5.18.			1.8.18	24.9.18.			30.11.18.			3.3.19.				10.5.19.			18.7.19.			6.11.19.			19.1.20.
Number of female flowers	14	:	:	:	9	14	27	30	*x*	30	29	18	16	16	18	*v*	9	23	20	26	42	38	29	22	17	24	16	6	*x*	*x*
Date :	11.5.18.				24.9.18.		30.11 18.			3 3.19.				10.5 19		18 7.19.				6.11.19.				19.1.20.			21.3.20.			
Number of fruit which set	9		...		4	7	9	9	...	19	16	6	10	4	3	.	4	5	6	7	8	14	18	2	4	14	5		...	...
Date .	30.11.18.				3.3.19.		10.5.19.			14.6.19.	18.7.19.	16.10.19.				19.1.20.			21.3.20.		17.5 20.			17.7.20.			16.9.20.			
Number of nuts harvested	3		...		4	7	9	9	...	19	16	6	10	4	3	...	4	5	6	7	8	14	18	0	4	14	5		...	...
Number of barren nuts	6		...			...			...		...			...		...			...			...		2						

leaf axils were barren and one flowering branch produced only male flowers. There is no necessity to count the female flowers till the bunch is harvested, when the scars of the dropped flowers and of the ripe fruit can easily be counted. There is little difficulty in training labour which is accustomed to climb trees to do the actual counting of nuts as long as this is supervised from the ground. All that is necessary is to impress on the climber that the next oldest bunch is some 140 degrees to the right or to the left of the previous one according to the direction of growth of the tree in question. In this way it is possible to definitely select certain trees which can be marked for the collection of seed nuts.

It must be remembered, however, that the coconut flower is seldom, if ever, fertilized by the pollen of the same tree, and that there is always the possibility that the fruit have been fertilized with the pollen from trees which have poor bearing qualities. It is quite within the bounds of possibility that in time steps will be taken by intelligent growers to ensure the male parentage of the seed nut by a system of artificial pollination. Though it has been proved that coconut pollen can be kept for several days without losing its vitality, as far as the writer is aware no experiments have as yet been made to see how far it is possible to utilize this information for the artificial pollination of the female flower. If this can be done, then it will be possible to determine the male as well as the female parent of each seed nut. There is no doubt as to the importance of this research. Favourable estimates place the maximum number of nuts which on an average a plantation can produce at sixty nuts per tree per annum. There are, however, many trees grown under ordinary plantation conditions which regularly bear more than double this number, and there seems to be no reason why the number of such profitable trees should not be greatly increased if more attention were paid to the parentage of the seed nut. It must be remembered that the crop will be on the ground for forty to fifty years at least, and that therefore the initial cost of the seed is of small importance if, by more care being bestowed on its parentage, the annual crop can be increased even by 50 per cent.

The general practice when harvesting seed nuts is to lower them from the tree and not to allow them to fall to the ground. Whether this is of importance or not is a matter of opinion. Where the nuts stay on the tree till after they have commenced to germinate, which happens in countries where there is an evenly distributed rainfall and a moist atmosphere, it is probably important, since, by falling, the "apple" within the nut may be damaged by the shock of the fall; but where the nut falls of its own accord when it ripens it is probably of little importance, as not more than about one in a thousand nuts is likely to be damaged by the fall. This statement is made after the examination of thousands of nuts which have been harvested and stored for making copra. It is very seldom that any damage is noted in such nuts. After all this is Nature's way of sowing the seed, and provision is made to break the effects of the fall by the husk drying out as the nut ripens, which gives the fruit considerable resiliency.

The number of seed nuts which are required for planting out a definite area should be at least 50 per cent. more than the number of trees required. The writer prefers this number to be 100 per cent. Though the percentage of nuts which germinate is high, and may be safely averaged at 85 per cent. of the nuts sown, there is a great difference in the time which the nuts take to germinate, which may be from four to eight months before the shoot is visible. Those which germinate first invariably give the best seedlings, and it would probably be advisable to discard all seed nuts which have not shown the shoot at the end of six months from the time of sowing. Then there is the question of selection. Since the seed nuts are all of mixed parentage, there is naturally a considerable variation in the seedlings. It is quite possible to pick out in the nursery those seedlings which will give a tree which will have a long weak leaf stalk as well as a long weak fruit branch stalk. Even in the seedling stage, when the seedling has not more than three leaves, it is possible to pick out such plants. These have a long narrow leaf blade and a long slender leaf stalk—what one would describe as "leggy" seedlings. These should all be discarded as likely to produce unprofitable trees.

In the chapter on the "Root System," a table has been given showing the amount of variation there is in the rate of root development. The matter is still under investigation, but it is probable that the future growth of the tree is dependent on this. It may be possible in the future to state definitely whether this is so or not, but investigation on such a point and with such a crop takes a considerable time.

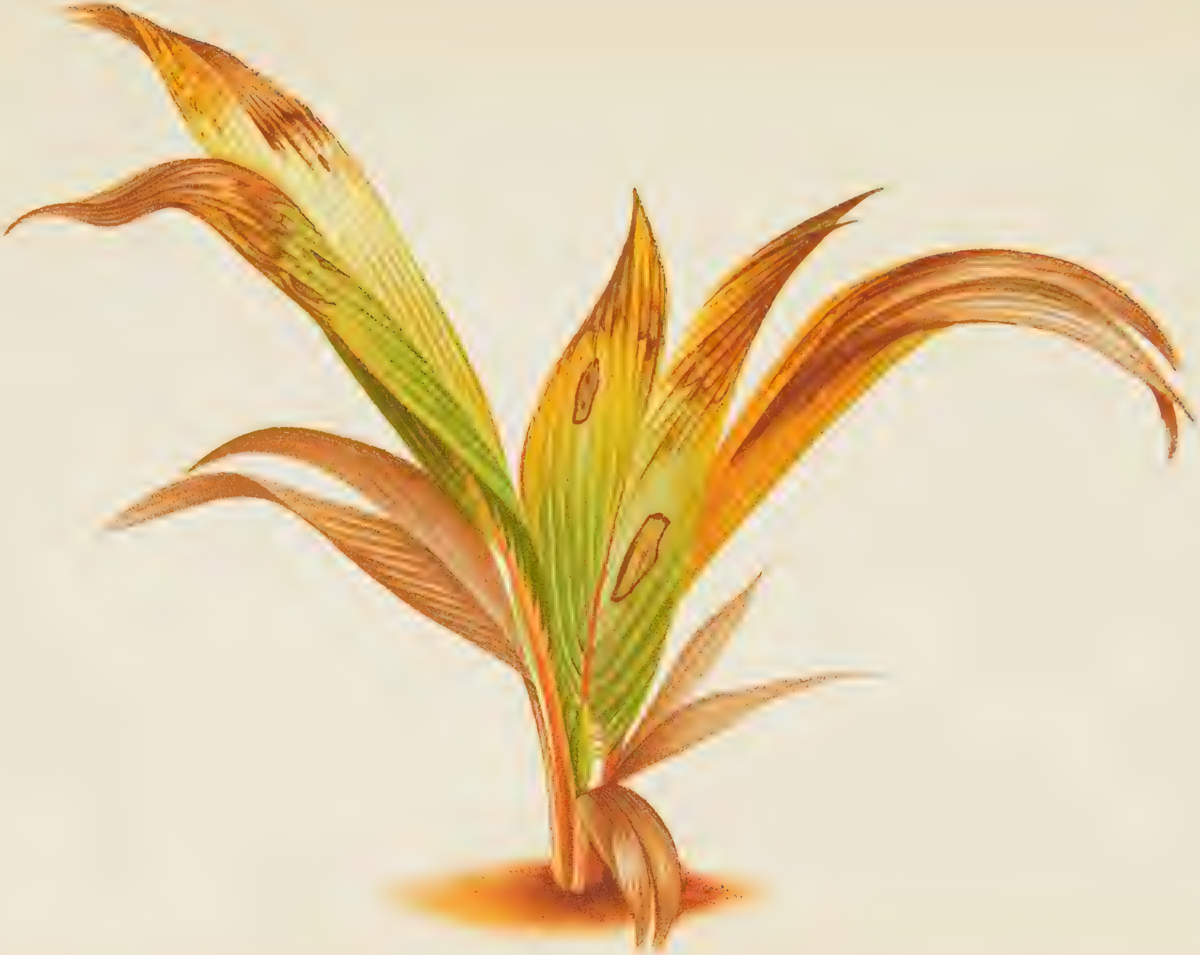
THE NURSERY OR SEED BED.

Some people advocate the sowing of the seed *in situ.* That is to say, in the place where the tree is to grow. In such a case no seed bed is required. The obvious defects of this system are, firstly: that it is not possible to do any selection of the young tree and to eliminate those which are undesirable; and, secondly, that it is not always possible to give the amount of drainage necessary for the proper germination of the seed nut. Further, it is not possible to give the young plants the same amount of protection that they would get in the nursery either from wild animals, fire, drought, or from the heat of the sun.

The nursery, therefore, may be considered as essential. The season of the year when the nursery is laid down is dependent on two main considerations. Seed nuts are usually collected at those seasons of the year when the development of the ripe nut is best, and the sowing of the nursery cannot be delayed for more than two months after the nuts are ripe. This is specially important in those countries where the rainfall is not well distributed, as in such cases there is a very great difference in the size of the nuts at different seasons. Where the rainfall is evenly distributed, this may not be of such importance. Secondly, there is the consideration of the time of the year when planting out can be done. This is again a matter of great importance in countries where the rainfall is not well distributed, though probably of minor importance where the rainfall is even throughout the year.

The soil selected for the nursery should be as open and free working as possible. In fact, pure sand probably makes the best seed bed. This should be laid out in strips some 8 feet wide, and the soil between the strips should be thrown on to the surface of the beds so as not only to raise their level but to provide adequate surface drains to drain off heavy rain water. When made, the level of the beds should be some 9 inches above the level of the bottom of the drains. This ensures the perfect drainage which is so essential to the young plant. Very often a part of an existing coconut plantation is selected as the site for the nursery. This provides the partial natural shade which the young plants require. Too heavy shade is to be deprecated, as this tends to draw up the seedlings. It also makes them delicate and unable to withstand the exposure which they will inevitably receive when they are planted out. If no natural shade is available and prolonged dry weather is expected, a light artificial shade can be made of plaited coconut leaves.

The nuts are spaced in the nursery about one foot apart. The position in which the nuts are placed and the depth to which they are buried vary in different countries and parts of the same country. In some the seed nut is placed in the ground upright with the leaves of the perianth uppermost, i.e., with the end of the nut with the germ uppermost. The only objection—and it is a serious one—to this method is, that the scale leaves of the perianth are very liable to



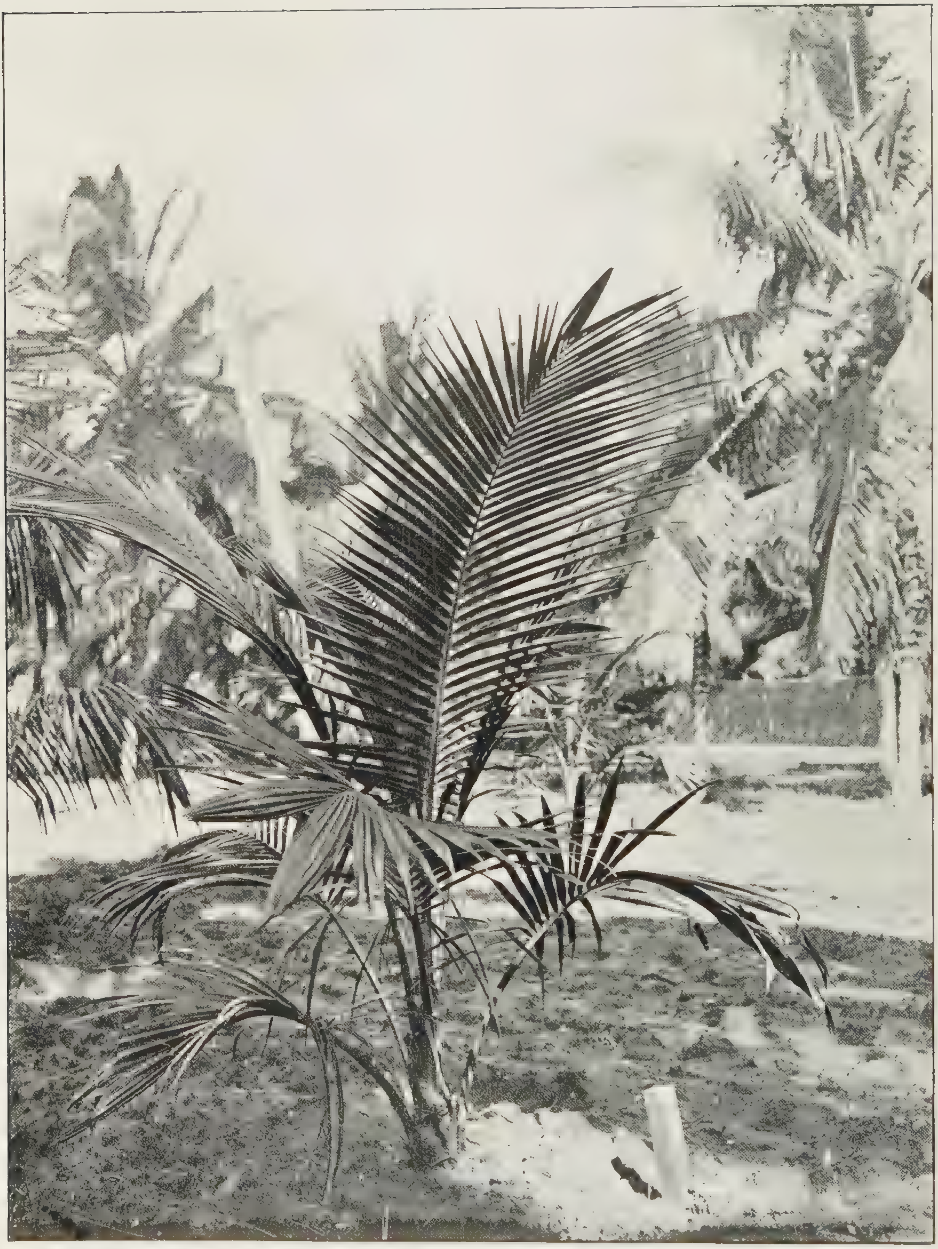
Seedling attacked by the fungus *Pestalozzia palmarum.*

harbour scale insects as well as the spores of the fungus *Pestalozzia palmarum.* This fungus is common in most coconut producing countries, and though it is of little consequence in the case of grown trees, as it usually only attacks the older leaves which are past work, it causes serious damage to young seedlings. The leaf of the seedling is undivided, and the fungus spreads rapidly right across the leaf, and not only this, but it infects the next leaf as soon as it is formed. (Plate XXIII.) The other general method of planting is to lay the seed nut on its side. This is the natural method, and is probably the best, as the young shoot has then to force its way through the smooth clean surface of the fruit coat. It is best to place the seed nut so that the germinating "eye" is uppermost. The method of ascertaining this has already been described on page 76. This ensures that the shoot has the shortest distance to travel to the surface of the fruit, and at the same time ensures that the roots which are formed from the base of the shoot have the maximum distance to travel and form branch roots within the husk before they find their way out into the soil.

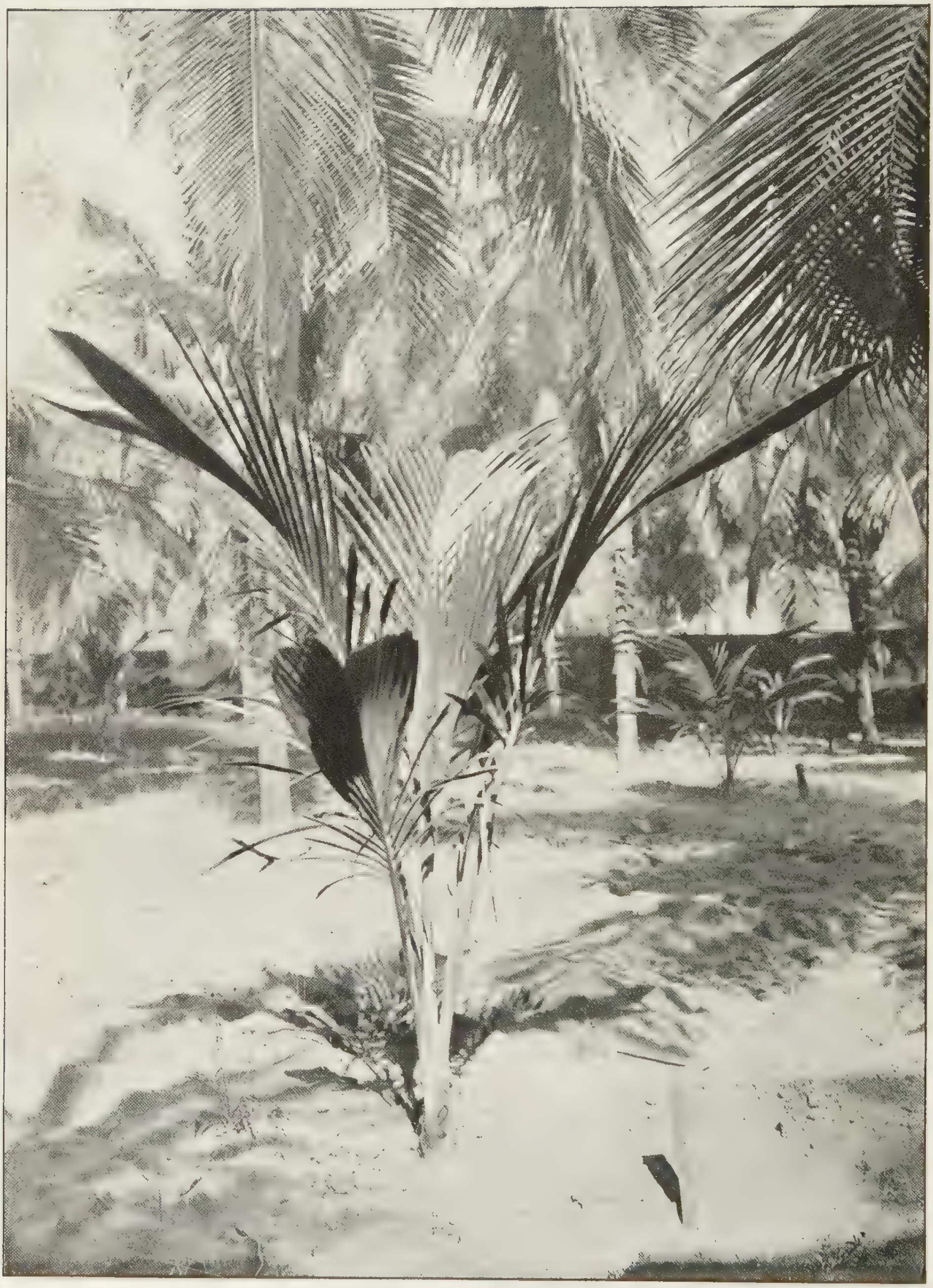
The depth at which the seed nut is planted in the seed bed must be decided according to local conditions. In a moist climate, with a well-regulated rainfall throughout the year, the nuts are often merely placed on the surface of the ground; but where the rainfall is uncertain and the air is likely to dry out the soil, the nuts are buried so that only the top of the nut shows above ground. In some places it may be necessary to water the nursery. If this is the case, a mulch of straw or dried grass on the surface of the ground will reduce this to a minimum. Watering is always an expensive item. Sometimes the preservation of a soil mulch around the seed nuts is all that is required to maintain the necessary amount of moisture in the ground.

Some people advocate the manuring of the nursery, but in the opinion of the writer this is quite unnecessary, and even objectionable. The seed nut is amply provided with a sufficiency of plant food for the development of the seedling till the time that it is ready for transplantation. The presence of manure in the nursery not only tends to the excessive development of fibrous roots in the nursery soil, but it attracts insects which may cause considerable damage to the young plants. Among such pests may be mentioned the rhinoceros beetle which breeds in decaying vegetable matter, and is at the same time very partial to the tender shoot of the coconut. The white ant is another pest which is to be feared. This will always find its way to a soil where there is much organic matter and will, when the supplies of this are exhausted, not hesitate to attack the husk of the seed nut which is an important reserve food supply for the young plant. For this, if for no other reason, the lightest of soils is recommended for the nursery, as the attack of white ants will be much less probable in such.

Other things being equal, the seedlings should not be left in the seed bed any longer than is necessary. In parts of Southern India these are transplanted when the shoot has just emerged through the husk—what is aptly described as the "crow's beak stage." The advantage of planting at this early stage is that the root system has hardly developed and



A good type of young plant. Note the thick short leaf stalk and the wide leaflets arranged close together.



A "leggy" young plant. Note the long slender leaf stalk and the narrow leaflets arranged far apart.

very little injury is caused to the young plant when it is lifted. The disadvantage of planting at this early stage is that it is not possible to make any selection of the right type of seedling for planting and it is much better to wait till the young plant has obtained its first three leaves. It is then possible to discard such as show signs of being "leggy" seedlings. Plate XXIV shows a young tree of good type with stout short leaf stalk and leaflets close together. Plate XXV shows a young plant grown from a "leggy" seedling. If the seedling is left in the nursery any longer than this it is greatly weakened when it is lifted, as it is impossible to lift the seedling, carry it to where it is to be planted, and to plant it without breaking or damaging most of the roots.

It is impossible to fix the age of the seedlings when they should be lifted as this varies even within the same seed bed, and it also varies very much in different countries. Seedlings which may be four months old in one country would not reach the same stage of development within double that period in another.

Where only a small number of seedlings are required, it is often the practice to grow these without even planting them. Two seed nuts are tied together by stripping a length of the rind of the fruit husk and with this tying two nuts together. These are then slung over a horizontal pole and kept in the shade, or over the branch of a tree, and left to germinate. This, however, is only possible in a country where the atmosphere is uniformly moist and the husk of the nut is not allowed to become too dry. One advantage of this method is that the roots do not try and force their way through the husk till the young plants are finally planted out. There is thus very little fear of the seedlings failing after they are planted in their permanent home.

Where the climate is too hot and dry for the young plants to thrive after they have been planted out at this young age, a practice is sometimes adopted of keeping the young trees in a nursery for as long as three years, or until the tree has been "weaned," and, besides having formed an adequate root system, has at the same time formed a new food reserve in the "cabbage" to replace that already exhausted in the "apple." It is obvious that this method is not applicable to places where the crop is grown under plantation conditions, but at the same time it may be of use to describe it as there are always a small percentage of failures which have to be replaced, and replacements should always be done with plants of the same age and development as the main planting in order to keep the whole plantation uniform in growth. The seedlings raised in the nursery should be planted out in a second nursery when they are about a year old. The soil in this second nursery should be selected for its good drainage and should be fairly light so that the plants when required can be easily lifted. The ground should if necessary be heavily manured so as to give the plants a good start. When the land is ready the seedlings are planted out about 4 feet apart with the top of the nut just below ground level. Afterwards the ground around the plants is kept free from weeds and the surface soil is kept loose. At the end of the second year the ground is again manured and the manure is hoed in. Usually at the end of the third year the trees are sufficiently developed to be transplanted. They are then lifted, the roots being cut off with a sharp knife about 1 foot away from the bole. Such roots, unless they are damaged within the remaining part, will soon send out branch roots which will take the place of the main roots cut off. Besides this the plant will at this stage be sending out numerous fresh roots from the base of the bole. This method is a common one of establishing small plantations on the East coast of India where the rainfall is insufficient and the air is too hot for the trees to be established with any degree of safety from the young seedling. It is also adopted sometimes near the coast where the sand is liable to shift before the trees are large enough to be able to withstand sand being piled up round them. When such young trees are planted out, all but the last two or three leaves formed should be cut and even the ends of those remaining should be shortened. This not only prevents loss of moisture from the leaf surface, but prevents the plant from being moved by the wind till it has developed new roots to anchor it in the ground.

PREPARATION OF THE LAND FOR PLANTING.

Land available for coconut planting can roughly be divided into three classes : (1 open grass land, 2) scrub jungle, and (3) high forest.

Grass Land.—This requires less work to get it into order for planting than any other. It may be land which has been abandoned from cultivation, or it may be land which has been denuded of forest growth by constant damage done by the people, or again it may be natural grass land covered with high grasses such as are to be found in large areas in East Africa. Where it is land abandoned from cultivation it is as well to note the nature of the grasses found growing on it. Such grasses as Imperata grass and *Saccharum spontaneum* are specially bad weeds, and if they occur they should be eradicated before planting is commenced. *Cynodon dactylon* or Bermuda grass may also prove troublesome, but as this is a grass which grows rather on heavy land with a dryer climate than suits the coconut, it is not so much to be feared. *Panicum repens*, which can be recognized by its grey green foliage and its thick knotted rhizomes, which give it the name of the "ginger-rooted grass" in Southern India, may also prove troublesome especially on lighter classes of land, but as it is not a deep-rooted grass it is not difficult to get rid of, if taken in time. Probably the worst of these grass weeds is the Imperata grass, known as "lalang" in the

Malay Peninsula. This, however, is not specially deep-rooted and will yield to cultivation. Such grasses should, if possible, all be killed out before planting starts and a careful watch should be kept for some time to see that they really are eradicated.

Open grass land should be ploughed up before planting is commenced. If a cultivator is worked across the ploughing when the weather is fine and the surface is dry, most of the grass will be killed. The great thing is to do the work at the proper time. It should be done before the roots of the grass loosened by the ploughing have had time to re-establish themselves. A spell of fine weather should be selected, for if rain follows the cultivation, the grass will only re-establish itself with greater vigour in the freshly loosened soil. If this operation has been successfully carried through, most of the grass will have been killed out and all that is necessary is to see that this is so. If it is seen that the grass is re-establishing itself, a further cultivation will be necessary.

Scrub Jungle.—This is possibly the most costly of all land to clear for planting. The very fact that it is scrub jungle indicates that the species of trees found growing there are those which it is most difficult to eradicate. This is specially so in thickly populated areas, and here most of the tree growth belongs to species which are capable of making coppice growth from the stumps of the original forest flora. Further than this the land is infested with perennial shrubs, many of which seed freely besides being difficult to eradicate. Thus it is not merely a question of removing the stumps of dead trees, which is a comparatively simple matter. These stumps are not only alive but they are deep seated and broken down, and may be likened to the fangs of a decayed tooth. As long as they remain in the ground they are capable of sending up new growth. Very often such scrub jungle is infested with weeds, which are very difficult to keep subsequently under control. An example of this is the lantana in Southern India which, though an introduced plant, now overruns large areas of land suitable for planters' crops.

In the case of scrub jungle land there is nothing for it but to stump the land and subsequently to keep it under cultivation. If the scrub jungle growth is heavy the soil will have gained greatly in fertility and all weeds will grow apace when cultivation is once started, so that the cost of keeping the land clean is great.

High Forest.—The preparation of such land is not so difficult as one would imagine, provided that experience is available in dealing with it. In the first place there is very little undergrowth if the forest growth is good, and annual as well as perennial weeds are therefore not much to be feared. Secondly, fire is largely used for the purpose of clearing the ground. Clearing is commenced at the close of the rainy season and everything up to a diameter of about 8 inches is cut. This is left on the ground for about two months to dry. The whole area is then gone over again with the knife and all subsequent growth is cut. The clearing is then ready for burning. A day is chosen for the fire when the prevailing wind is sufficiently strong to carry on and spread the fire. A successful burn will clear off everything that has been cut, but if the fire has missed anywhere this should immediately be burnt. All the larger timber left on the ground is then felled at about 3 or 4 feet from the ground. If it is soft wood of no value it is cut up *in situ* for further burning. If the timber is of value and the owner of the land has a right to it, it is drawn out of the forest after it has been stripped of its branches. By the time that the area has been gone over in this way there is a large quantity of material available for burning. Not only the foliage and branches of the trees which have been felled, but the secondary growth which has sprung up since the first burn. Such material as is obtained for burning during the felling is placed in rows so that, when the clearing is again fired, the fire may be continuous if this is done when a wind from the prevailing direction is blowing. A final burn is made after this when all stuff which is not burnt has to be disposed of. In this final burn the object is not only to dispose of this, but also to get rid, as far as possible, of the stumps of trees left from the last felling. All material is now collected round these stumps where they may burn for several days. Except for digging drains and laying out, the land is now generally considered ready for planting. Stumping is very seldom done as this is considered| unnecessary expenditure. The majority of these stumps will disappear within two or three years, as the action of fungi is very rapid in the moist tropical climate which suits the coconut. Any stumps of wild palms left after the final burning should however be removed and burnt, as these will prove a serious menace to the future coconut plantation in that as they decay they harbour the two most serious insect pests which attack the coconut: namely, the coconut weevil and the rhinoceros beetle.

Under such conditions of clearing it can be realized that any systematic cultivation of the ground other than by hand is out of the question. In this case, however, it is not such a serious matter, since the early growth of the coconut on this rich virgin soil is sufficiently rapid to render this of minor importance during the early years of the plantation, provided that weeding is done regularly and systematically. It is essential that the weeds are not allowed ever to begin to smother the young plants.

When the land has thus been prepared the next steps are to line out the position of the future trees, to protect the area from soil wash, to see that all parts of the estate are properly drained, to lay out main and feeder roads dividing the land into suitable working blocks, to decide on the line of main drains and to fix the site for copra dryers, permanent quarters for the staff, for permanent coolie lines, hospitals, &c. It is necessary even at this early stage of the plantation to have some definite plan of operations for dealing with the crop when this begins to come in. Where the land is undulating a contour survey should be made. This is essential for fixing the line of main drains as well as for protecting the soil from wash.

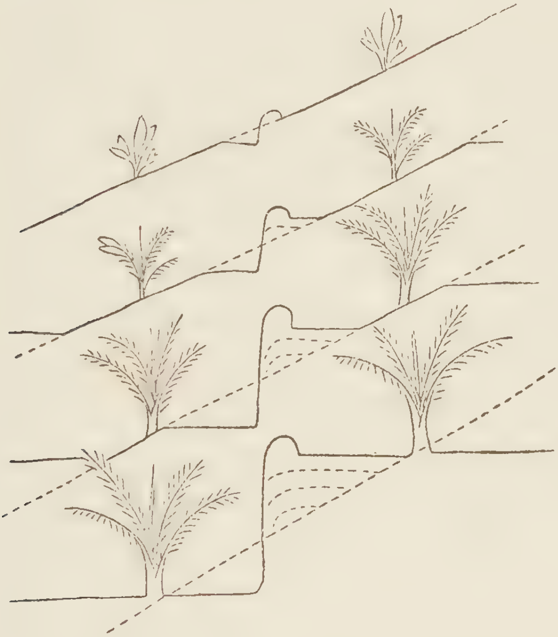
The distance between trees needs careful consideration. Where there are other plantations in the neighbourhood grown under similar soil conditions it should not be difficult to determine this. This distance should be 4 feet less than twice the length of a well developed leaf of a full grown bearing tree. Thus supposing the leaf is 18½ feet long, $18\frac{1}{2} \times 2 - 4$, or 33 feet will give the approximately correct distance. This distance is based on the axiom that the coconut tree requires that the whole of its foliage should be able to reach the full sunlight, as it is on this that the future crop of the plantation depends. Theoretically the distance between trees should be twice the length of the leaf, but no leaf is ever quite horizontal, and even though the lower portion may be, its tip will droop. Further than this the weight of the fruit bunch will very soon force the leaf out of the horizontal.

Too close planting cannot be too strongly condemned. A tree must have full light if it is to carry a full crop of nuts, and this point is too often lost sight of in buying or valuing a property which has already been planted up. Any defect in the spacing cannot be subsequently rectified. The tree has no branches and it cannot therefore rectify any break in the cover made by an attempt to thin out trees where these are overcrowded. The basis of value is not the number of trees to a given area, but the number of nuts which those trees can produce under proper management. It is safe to say that the ordinary copra varieties of coconuts should never be planted closer than 30 feet apart. The development of the crown must be taken as the basis of spacing. The development of the root system, provided drainage is good, is quite a minor consideration.

Since the development of the crown is to be taken as the basis for spacing, the question is how to arrange the trees so as to get the greatest number to the acre without interfering with this. The general method of spacing is to arrange the trees at the four corners of a square. This, however, is very extravagant of crown space. The most economical method is to plant at the three corners of an equilateral triangle. At 30 feet apart this will give fifty-six trees to the acre against forty-eight when these are planted at the four corners of a square.

This system of definite spacing can be followed where the land is level, but where this is on a slope, it is preferable that, as far as possible, the planting should follow the contour. This is so as to be able to prevent surface wash. Further, on an incline the trees should be given wider spacing so as to counteract the slope in its effect on the amount of light which the crown will get. That is to say the minimum distance should be that decided on, but measured on the horizontal and not on the slope. The steeper the slope the more necessary is this precaution. All land planted on the slope should ultimately be terraced, and preparation for this should be made at the time of planting. Since therefore the terrace must follow the contour, the planting must also do the same.

Much can be learnt from the people of the country as to the best methods of terracing, at any rate in those countries where agriculture is developed; and for a crop like the coconut the method adopted by the people of the Malabar coast would be difficult to improve upon. Here the rows of trees follow the contour, and according to the steepness of the gradient there may be one or more rows of trees on each terrace. The position of the edge of the terrace is decided on and is between two rows of trees. Soil is then taken from below this imaginary line and thrown along the line of the terrace, making thereby a low but wide wall. The space between the edge of two terraces is kept under cultivation, and during heavy rains the soil is washed down the slope to be held up by this wall, which has previously been



well beaten to consolidate it. The space above the wall is thus gradually levelled, and when it is filled up nearly to the top more soil is again thrown on to it from below. This again is well beaten and the process is repeated till the whole terrace is level. In this way steep hill-sides are planted up with coconuts, and there is often a drop of 4 to 5 feet from one terrace to the next with only one row of trees on each terrace. This method of terracing might well be adopted for other permanent crops which are grown on a similar class of land, such as tea and rubber, instead of the evenly spaced rows which one sees running down steep hill sides, which render any method of efficient terracing impossible without injury to a large number of the trees. The various stages of this terracing are shown in the preceding diagram.

When the terrace is once made all that is necessary is to see that the edge is kept under repair, freed from weeds, and that it is well beaten at the close of each rainy season.

Holing.—Having marked out the places where the trees are to be planted out, the next operation is the preparation of the soil to receive the young plant. It is essential that the young plant should be placed in a rich fertile soil, and it therefore depends on the fertility of the soil what preparation is necessary. Here the word fertility is used in the wide sense to include physical as well as chemical fertility. A soil which from analysis may be shown to be very fertile may be so badly drained that the plant food shown in the analysis is not available to the plant. The necessity of giving the young plant a good start can be seen from the illustrations of the young seedling in Plate I. The young plant has still a reserve of food, but this is much reduced since germination commenced and this therefore should be considered as an "emergency ration." If the seedlings are not too old the root system will still be small, but the young plant will have made preparation to send out fresh roots, and with the whole of the husk now buried in the damp soil, these find no difficulty in making their way through to the soil. In some countries where most of the land available for planting is high forest and the soil is naturally very fertile there is no necessity to make any previous preparation of the planting hole. This is made at the time of planting and is only sufficiently large to hold the seed nut, so that it can be covered without difficulty with soil. Planting under these conditions is light work. Where, however, the soil is not so fertile, the planting hole must be made much larger, while on very light sandy soil the holes should not be less than 4 feet across at the surface and 3 feet at the bottom of a 3 feet hole. Such work adds greatly to the cost of planting, but if the soil is not too rich it is well worth the expenditure, since a full vigorous stand will soon be obtained which will assist greatly in keeping weeds in check in the future. Where such planting holes have to be made it is as well to have these made some two or three months before planting is actually contemplated as this will allow the soil to weather. The soil removed from the holes should receive manure which should be thoroughly mixed with it before it is returned around the seedling. Both lime and potash as well as a certain quantity of phosphates seem to be required at this stage, but of course the actual manure to be used will vary in different places according to what is available and what is wanting in the soil. It is sometimes recommended that rich soil should be brought for filling up such planting pits, or at any rate that surface soil should be used, but where the soil is itself poor there is little difference in the fertility of the surface soil and that below. Bringing fresh soil from elsewhere is a costly business and since the main roots of the tree very soon get beyond the planting hole as is shown in Plate I, it is very doubtful whether this would prove sound economy. If the texture of the soil is good and does not contain anything injurious to the growth of the coconut, the addition of suitable manure seems to be all that is required in practical planting.

The soil should be partly returned to the pit after the manure has been mixed with it. The planting season is selected when frequent rains are expected, and unless this is done there will be a considerable loss of manure from surface wash. When the soil is returned to the pit, it should be thrown on to the centre of the floor. This will cause the soil to rise in the pit in the form of a cone. The hole can be filled in till the top of the cone is level with the ground. At the same time the soil around the sides of the pit should be pressed down with the feet. Rain will cause this cone to settle down by the time that the young tree is planted. This is of importance, otherwise it will be found that after the planting has been completed the soil will settle two or three inches, and that water will stagnate round the seedling after rain.

When everything is thus made ready, the seedlings have to be lifted from the nursery. It will be found in practice that it is impossible to lift the seedlings, carry them to the planting place, and set them in the planting hole without damaging the longer roots. These are very easily damaged, being at this stage unprotected by hardened tissue. They do not break off altogether, but the outer layers of the root get damaged, which causes the admission of water into the root, which then dies at the point of damage. Usually this damage is situated just where the root emerges from the husk of the nut. Many growers therefore do not worry about lifting the seedling without damaging the root system, but merely cut the roots off underneath the seedling with the blade of the sharp wide hoe which is usually used by natives in the tropics for digging. It can thus be seen that the younger the seedling is the less damage is caused to the root system when it is lifted.

If the lining out has been properly done each plant will rest on the centre of the planting hole, but it is as well to check this by looking along the line and indicating to the man actually planting the exact position where the seedling should be. Not that there is any material advantage in having the lines absolutely straight, except the moral one that the standard of management should be of the highest. This is more important than might be thought, especially when working with coloured labour and overseers, as their standard of work must at all costs be maintained.

The general rule should be that the top of the seedling is just buried when the soil has been pressed round the planted seedling. Where the tree lies in a slight depression allowance must be made for this by planting not quite so deep. In this case the soil should be slightly mounded up round the plant so as to cover the nut. This, if the mound is wide enough, will prevent surface water from standing round the seedling. Where the plant is on a slight elevation the reverse process is necessary.

There are exceptions to this rule. Where the plantation is influenced by tidal action, and the tidal water level is likely to rise within reach of the seedling, instead of making planting holes, soil or sand must be brought from elsewhere and piled in a heap at the place where the young plant is to be planted. This will then be planted on the top of this mound. Large areas of tidal backwater are planted in this way in Southern India, fresh soil being gradually brought in to raise the whole level of the ground.

The young seedling is extremely sensitive to stagnant water even for a short time, and this must not be allowed to stagnate round the young plant, otherwise, though it may not actually die, it will take a long time to become established.

In some countries there is a practice of planting the seedlings below the ground-level of the surrounding land. This causes a great lack of vigour and very slow growth. Many of the young plants die, and have to be replaced, and it often takes five years or more before the tree is considered to be established. By this time the pit in which the young tree was originally planted has usually silted up and the tree has managed to send its feeding roots near to the surface. This is the usual method of planting adopted by native growers on the Malabar coast. The idea seems to be that by deep planting a deep root system is developed and the plant is thereby protected against the long dry weather. The people never seem to have realised that a surface soil mulch is a much better protection against drought than this method of deep planting. Such deep planted trees often take fifteen years to come into bearing. This not only means a long time for capital to be unproductive, but means many years of unkeep to be met without any return.

CULTIVATION.

This chapter may appear out of place here, but as the care and upkeep, both of the young plantation and of the plantation when it comes into bearing, are largely dependent on a knowledge of this, it has been included here.

Methods of plantation management, at any rate as far as the East is concerned, are based very much on tradition, and the value of cultivation has been to a great extent lost sight of. In the East far too much money is spent on hand cultivation, and, since every year plantation labour is becoming more and more expensive, many estates are forced to the false economy of reducing cultivation to a minimum; and this minimum is too often at the expense of efficiency.

Many planters again do not realise the value of cultivation. Till the introduction of rubber as a plantation crop, the majority of planters never had had any experience of working under tropical conditions. Their attention was mainly confined to such crops as coffee, tea, cinchona, &c., which are grown in the more or less temperate climate to be found at high elevations in the tropics. Level land at such elevations is hard to find, and the planter had of necessity to take up land which was so steep that manual labour was the only possibility. Hence cultivation was mainly confined to hand weeding, with an occasional forking. Many of those who had gone in for clean weeding were forced to give this up as their soil, being unprotected against surface wash, was rapidly disappearing, and so it came about that the necessity and reasons for cultivation were to a great extent lost sight of. With the introduction of rubber as a plantation crop, the planter came down to the real tropics, but he brought the methods which he had been used to with him—even on to the level coast lands where the use of tillage implements was quite feasible. Then followed coconuts as another crop of the true tropics, which lent itself to estate cropping, and the same methods were followed in this case also. The result is that coconuts never receive that amount of cultivation which is essential if the crop is to be a permanent success.

The writer has had the advantage of approaching this crop from an entirely different point of view ; namely, that of tropical arable agriculture ; and his own experience of the coconut, which has been confirmed by detailed inquiry into the methods of coconut cultivation among native growers on the Malabar coast, clearly shows that the permanent success of a plantation is largely dependent on the cultivation of the soil. There are planters also in Ceylon who have proved this for themselves. This also confirms the opinions and results of experimental research by fruit growers in the subtropical and temperate regions of the globe.

The objects of cultivation may be summarized as follows : The elimination of weeds. The conservation and distribution of soil moisture and the proper aeration of the soil. And the effects of both these on the root system of the crop.

The elimination of weeds has in itself a considerable influence on the distribution of soil moisture. Where the surface is covered with weeds, the roots of these tend to hold up a large amount of the rain water which falls on the ground. The weeds themselves utilize this, and where their roots are, there is a certain accumulation of organic matter which again helps to hold the water from penetrating deeply. The tendency, therefore, of weeds is to make the roots of the crop grow towards the surface in order to get their share of this moisture. Hence weeding in itself can be regarded as an important part of cultivation in that it allows rainwater to penetrate more deeply into the soil where it can become available solely for the use of the crop.

Though weeding is essential, it is of minor consideration when compared to the effects of cultivation. Ploughing or digging alters the whole soil physically as well as chemically. The distribution of water in the soil is regulated, and it is not subject to such rapid changes as when there is no cultivation. Rain, when it falls on a cultivated surface, is carried much more rapidly into the soil and subsoil, and, in its wake, air is drawn in. In dry weather, the same cultivation prevents the rapid evaporation of soil moisture from the surface, and the upper layers of soil contain much more moisture than is the case where there is no cultivation. This better soil aeration drives out much of the carbonic acid gas which is formed in the soil, especially in a soil where there are accumulations of organic matter; and it further encourages the development of the microscopic flora of the soil which are capable of fixing atmospheric nitrogen and rendering this available for the crop which is being grown on the land.

This better aeration has a great influence on the root habit of the coconut. Without it the small branch feeding roots will grow right up to the surface in order to get their share of air and water, and even the main roots will sometimes be found only just under the surface. Here they are very liable to damage, and a spell of dry weather will soon make itself felt, while a prolonged period of dry weather, coupled with the heat of the soil, will often kill these outright. If an old plantation is brought under cultivation for the first time, the bulk of the feeding roots which have made their way to the surface will be destroyed. The crop will feel this loss severely for a period of several months. In order to cut down expenditure, it will cease to form fruit branches for a time, and will devote its energies to the development of a deeper seated system of feeding roots. Subsequent cultivation, after this has been formed, will all be to the benefit of the crop. This deeper root system is protected against subsequent cultivation. It benefits by the better aeration of the soil, which not only supplies more nitrogen for the use of the crop, but also renders other plant food available. It regulates the supply and distribution of moisture, and the whole texture of the deeper soil is altered, which enables the tree to form a much stronger root development than ever it had before.

If cultivation is started when the plantation is first established, and is maintained throughout the growth of the crop, then the tree never suffers from the shock which it is bound to feel when cultivation is suddenly commenced in an old plantation. The deeper and protected root system is there from the very commencement, and is maintained throughout the life of the tree.

Plates XXXVI to XXXIX show the development of the root system of trees which are accustomed to cultivation. These have been exposed by removing the surface six inches of cultivated soil, and then by washing out the soil between the rootlets. Here in the surface six inches there was practically no trace of these feeding roots, although the photographs were taken at the close of the rainy season after some 150 inches of rain had fallen within a period of four months.

Where there is no cultivation these surface feeding rootlets will be confined to the surface 1 foot of soil, but where the plantation is systematically cultivated these will develop as deep as 3 feet in the soil, thus trebling the feeding area of the tree. This is, of course, provided that the soil is naturally well drained.

To illustrate the advantages of systematic cultivation the following example is given. A part of the Government coconut station on the Malabar coast consists of a plantation aged about twenty-five years. This was acquired in the beginning of 1917. It was in a neglected state when taken over, as the previous tenants had bestowed little attention on it. Their cultivation consisted of putting such house ashes as they had available round the base of the tree stems and possibly digging this in to a radius of 3 feet from the stem. The whole area except half of one block was ploughed up in July, 1917. At the end of the rains in October this was again ploughed and was subsequently cultivated to form a soil mulch for the coming dry weather. This system of cultivation has been followed each year since. One block was divided into two. One half was left as it was without any cultivation and the other half was cultivated as described above. The portion which was uncultivated became so poor in 1919 that the local system of cultivation was followed over a portion of the area, which consists of digging round the base of the stem, but though the trees have improved slightly, they have not yet commenced to bear any better crops. The yield of the two halves of this block, after eliminating those trees which bordered the two halves, is shown below:—

Average number of nuts per tree	1918	1919	1920 (10 months)
Uncultivated (average of 50 trees)	17·0	16·7	7·8
Cultivated (average of 44 trees) ...	20·8	32·6	48·9

The cultivated block received no manure during the period covered by these figures and the whole improvement was due to the effects of cultivation.

In order to ascertain the effects of cultivation on the moisture-content of the soil and on soil water movement, two series of moisture determinations were made. The first on an area which was not planted with coconuts, and the second on the planted area where the figures of yield which have been given above were taken.

Samples were taken for each foot depth up to 6 feet. The first samples were taken at the close of one rainy season and subsequent samples were taken at intervals of fifty days till the middle of the next rainy season. In each series, samples were taken from land which had been cultivated and from land which was uncultivated, i.e., land under grass. Unfortunately it was not possible to have the two series taken under identical conditions of rainfall and soil, but in general these two factors are so similar that a fair comparison can be made. Both the rainfall and the mechanical analysis of the soil have been given of each series.

UNPLANTED LAND WHICH HAS BEEN PLOUGHED AND CULTIVATED.

Date on which samples were taken	Rainfall during the preceding fifty days	Percentage of moisture at the following depths					
		1st foot	2nd foot	3rd foot	4th foot	5th foot	6th foot
4.11.18	12·72	8·73	10·38	11·28	11·59	11·05	10·8
24.12.18	2·86	5·07	8·62	9·75	9·59	9·72	10·9
16.2.19	0·00	5·2	8·1	7·7	8·6	9·3	10·3
18.4.19	0·00	4·5	7·6	7·9	8·6	8·6	9·5
29.5.19	4·98	9·43	10·68	10·82	10·89	10·62	10·4
17.7.19	59·10	11·75	10·68	16·15	17·05	Saturated	

UNPLANTED LAND UNDER GRASS.

Date on which samples were taken	Rainfall during the preceding fifty days	Percentage of moisture at the following depths					
		1st foot	2nd foot	3rd foot	4th foot	5th foot	6th foot
4.11.18	12·72	8·81	9·91	10·4	10·5	11·4	9·9
24.12.18	2·86	3·73	6·46	8·24	8·77	8·84	9·4
16.2.19	0·00	3·2	4·4	6·5	7·9	8·7	9·5
18.4.19	0·00	2·2	4·8	5·7	6·5	7·5	8·5
29.5.19	4·98	9·73	8·80	6·76	6·15	7·21	8·1
17.7.19	59·10	9·75	10·54	11·14	12·6	14·00	15·3

The mechanical analysis of the soil and subsoil to which the above figures relate is as follows :—

	Surface soil Per cent.	Soil at 2½ feet depth Per cent.
Fine gravel	3·60	3·25
Coarse sand	66·21	62·33
Fine sand	16·38	14·52
Silt	2·30	3·57
Fine silt	5·30	7·39
Clay	5·06	8·10

LAND UNDER COCONUTS WHICH HAS BEEN PLOUGHED AND CULTIVATED.

Date on which samples were taken	Rainfall during the preceding fifty days	Percentage of moisture at the following depths					
		1st foot	2nd foot	3rd foot	4th foot	5th foot	6th foot
31.10.18	2·32	5·28	6·40	6·66	6·73	7·01	7·36
20.12.18	9·32	8·40	9·35	8·17	7·13	7·62	7·91
9.2.19	0·00	3·4	5·7	6·3	6·5	7·0	6 9
30.3.19	0·00	3·5	4·9	5·7	6·2	6·7	7·1
19.5.19	2·80	5·58	5·99	6·73	6·92	6·53	6·89
14.7.19	62·56 (56 days)	9·51	8·08	9·05	9·22	9·55	10·14

LAND UNDER COCONUTS UNCULTIVATED.

Date on which samples were taken	Rainfall during the preceding fifty days	Percentage of moisture at the following depths					
		1st foot	2nd foot	3rd foot	4th foot	5th foot	6th foot
31.10.18	2·32	2·65	3·55	4·47	5·21	6·08	6·36
20.12.18	9·32	8·92	8·77	7·09	7·42	7·53	—*
9.2·19	0·00	2·4	3·9	5·3	6·0	6·5	7·4
30.3.19	0·00	2·8	4·1	5·0	5·5	5·6	6·2
19.5.19	2·80	5·69	6·14	4·86	5·47	5·95	6·34
14.7.19	62·56 (56 days)	8·06	8·25	8·47	9·14	9·71	9·87

* Sample spoilt.

The mechanical analysis of the soil and subsoil to which the above figures relate is as follows:—

	Surface soil Per cent	Soil at 2½ feet depth Per cent
Fine gravel	22·33	20·87
Coarse sand	61·65	57·42
Fine sand	3·72	7·46
Silt	2·34	3·45
Fine silt	4·85	5·62
Clay	4·42	4·68

Both soils were a red sandy loam of great depth and the analyses show that they were very similar in character. The high figures for the samples taken from the planted areas on December 20 are accounted for by the fact that 2·69 inches of rain fell on December 18 and 19, immediately prior to the taking of the samples.

Comparing the unplanted areas, it will be seen that throughout the dry period, which exceeded one hundred days, the cultivated area maintained a higher moisture-content throughout the depth of 6 feet than the area which remained uncultivated; that, as soon as the rain fell in May, the cultivated area was able to absorb and distribute the moisture evenly throughout the first 6 feet of soil. In the uncultivated area this rain appears to have only affected to any extent the first 3 feet of soil. Certainly the first foot is more moist than where the cultivation has been done, but this is because rain water must have settled on the surface and has been unable to penetrate the soil—even a soil such as this where more than 85 per cent. consists of sand and fine gravel. The figures make it evident that much of the rain which fell on the uncultivated ground has had to run off without ever having had a chance to penetrate the soil. Even after there has been a rainfall of 59·1 inch during the last fifty-day period, the soil where there has been no cultivation is not so moist as that which has received cultivation.

Comparing the cultivated and the uncultivated areas where the land is under coconuts, it will be seen that generally the soil on the cultivated area has a higher moisture content than that which is not cultivated: and this in spite of the fact that the cultivated area is producing a far greater number of nuts than the uncultivated area. On December 20 both the cultivated and the uncultivated areas had benefited by the rain on the two preceding days almost to the same extent and thus were both equally prepared for the following dry weather. Throughout this period, which exceeded one hundred days without any rain the cultivated area retained more moisture than the uncultivated area, in spite of the fact that the former was ripening more than twice the number of nuts and was forming more than six times the number of young nuts. It is only at the 6-foot depth that the uncultivated area contained moisture slightly in excess of the cultivated area. This can be accounted for by the fact that the trees on the cultivated area had developed a much deeper root system than the others. After the rainfall of 2·80 inches in May, the soil moisture in the cultivated area was much more evenly distributed than in the uncultivated area, though after the continuous rainfall during the last fifty-day period (actually fifty-six days), which totalled 62·56 inches, the moisture content in the two areas was very similar.

Comparing the figures for the uncultivated area which is unplanted and that under coconuts, the figures of moisture-content at the end of the hundred-day dry period is very similar, thus showing that the trees have been practically standing still during this period. This is not the case, however, where the land has been kept under cultivation. Here the figures of moisture are very much higher where there has been no crop, which shows how the coconut has been able to maintain its activity throughout this dry spell merely by a system of cultivation.

The figures for the last sampling in the middle of the rainy season are of interest in showing what large demands the crop does make on the moisture in the soil. They are also of interest in showing, even when trees are planted as far apart as coconuts are, what an effect they have on the drainage of the soil.

Though it is not possible to demonstrate the effects of cultivation on the trees other than by the figures of yield, which have been given, it may be stated that where the cultivation has been done the trees are a dark healthy green and the number of leaves are nearly double the number that are on the trees which have not received cultivation. Further, the leaves on the latter are pale, stunted in size and present a generally unhealthy appearance. The dark healthy green of the foliage indicates that the trees are plentifully supplied with nitrogen. The analysis of the soil does not account for this, and the only conclusion which can be drawn is that the soil has some means of fixing the atmospheric nitrogen. Whether this is the work of soil bacteria, and if so what bacteria, has still to be proved. It may be that the fungus hyphæ of some symbiotic fungus which are invariably found in the root of the coconut have something to do with this fixation of nitrogen.

The table on the following page is the analysis of the soil in question and is the average of three separate samples.

Apart from the actual effects of cultivation there are other indirect benefits that the crop derives. Rats, which are often a severe scourge in a coconut plantation, do not like cultivation, especially when the weather is dry. They are then forced to go outside the cultivated area to form their burrows. In the same way ants which are often a pest in that they rear such insects as scale and meally bugs on the coconut, are kept in check. The operations of cultivation also bring to the surface many insect pests, and special mention may be made of the larvæ of the rhinoceros beetle, which are to found in any soil which is rich in organic matter.

	Soil Per cent	Subsoil Per cent
Loss on ignition	1·85	1·92
Lime	Trace	Trace
Magnesia	0·07	0·08
Total phosphoric acid	0·04	0·04
Total potash (K_2O)	0·16	0·18
Containing:—		
Nitrogen	0·031	0·022
Available P_2O_5	0·001	0·002
Available K_2O	0·002	0·002

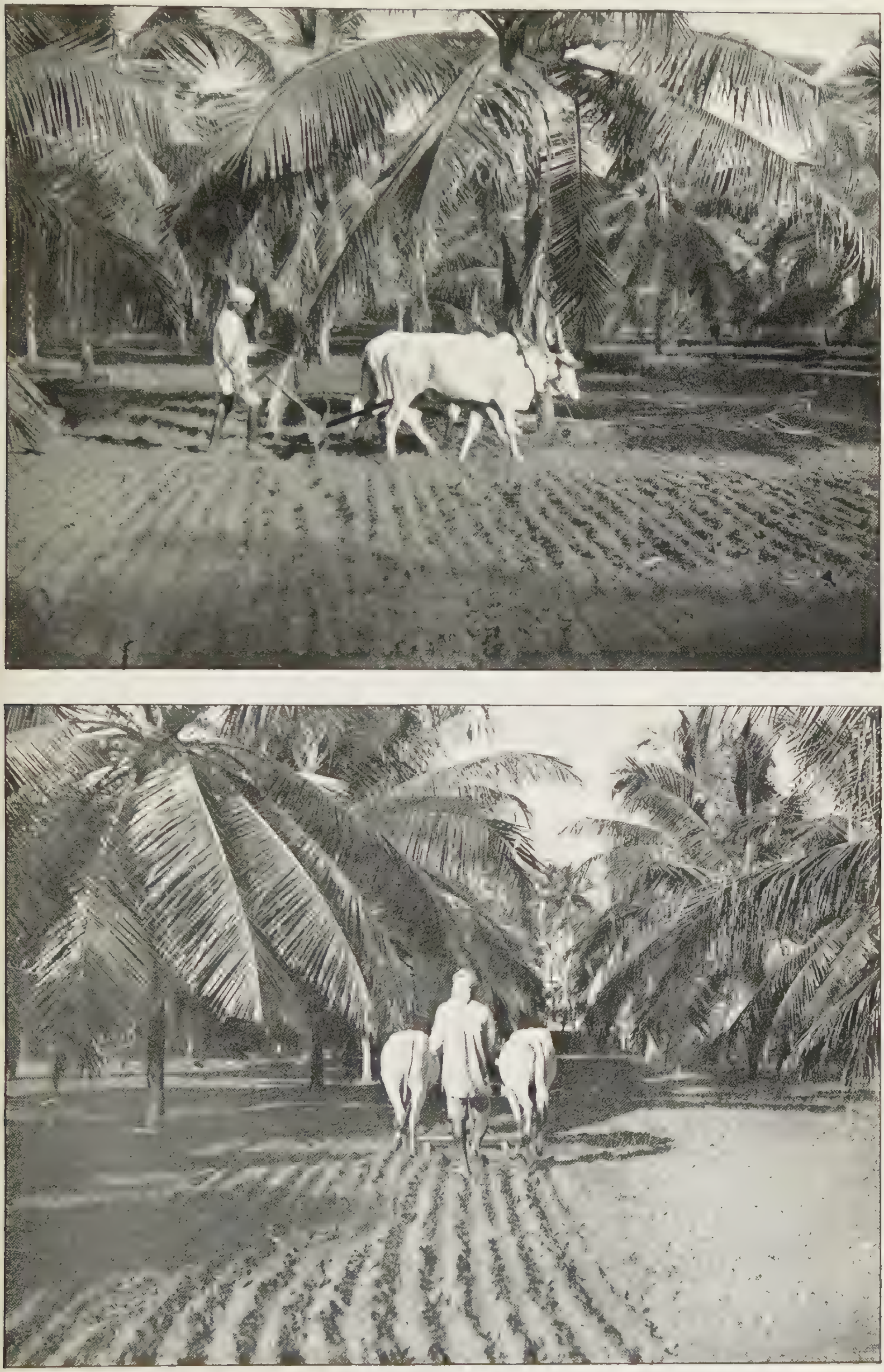
IMPLEMENTS OF CULTIVATION.

The choice of implements for cultivation is dependent on local conditions. In most countries of the tropics the common draught animals are either bullocks or buffaloes. If these are available they are undoubtedly the cheapest and most efficient form of draught. They are what the labour is accustomed to, and usually large numbers of these have in any case to be kept for carting, &c. The buffalo is a much more powerful animal than the bullock, but has the disadvantage that it cannot be worked through the heat of the day and that it is a much slower-moving animal. Where the soil is inclined to be heavy and a stronger animal than the bullock is required, the buffalo will probably be the most suitable. It has the further advantage that its initial cost is consideraby less. In some countries the buffalo has the reputation of being savage, but in others they are quite docile.

Whether the bullock or the buffalo is decided on, the mplements to be recommended are the same. These must of necessity be light, since it is not desirable to work more than a single pair to each implement. The implement must therefore be such that it can be worked by a single man. He must be able not only to control the implement, but guide the animals at the same time. This is essential if the cultivation is to be carried close up to the trees. If labour is accustomed to draught implements—and practically all labour employed in the East is—these should conform as nearly as possible to the type of such implements that the labour understand. The European pattern of plough is entirely unsuited to estate work. The animals are too far away from the driver and he has no proper control over them, nor can he turn in the same space as with his own implement. The type of plough required consists of a draught pole to which a small mouldboard plough is attached, and to this or to the bottom of the draught pole is fastened a short vertical stilt or handle. This is a modification of the indigenous Indian plough and an improvement on the Chinese plough. When ploughing, the point of the plough is right at the heels of the animals and the driver has full control as he walks alongside the implement. The setting of the plough is made by adjusting the length of the draught pole according to the height of the yoke. The guiding of the plough is very similar to that of the European plough and is done by the driver drawing the handle of the stilt either towards or away from him. Two very useful ploughs of this type are made in England. The "Monsoon" plough made by Messrs. Ransomes, Sims and Jefferies, and the "Vitis" plough made by J. and F. Howard of Bedford. These are ploughs which any ordinary estate labour can very soon learn to handle and on an ordinary light soil can plough up to 6 inches deep. For a first ploughing a man and a pair of cattle can plough about half an acre a day and for subsequent ploughings about three-quarters of an acre per day.

For the same reason that this light type of plough is advocated, a light cultivator built on the same lines will be found most suitable. Such an implement is shown at work in Plate XXVI. The same idea of the draught pole and stilt is incorporated here and the driver has full control of his animals. The implement shown is one made by the Mysore State Department of Agriculture. It consists of six curved tines, three at the back alternating with three in front. These are fastened to a small framework built on to the draught pole. The three front tines are longer than those at the back, so that when the draught pole is fastened to the yoke, all the tines penetrate the soil at the same time. With such an implement and working on land which has been previously ploughed a man and a pair of cattle can cover over three acres a day.

In some countries the light disc cultivator has been introduced for preserving a soil mulch, but it is doubtful



Preserving the soil mulch. A bullock cultivator at work.

whether this is as efficient as the small implement described above, except perhaps on a heavy soil where it is necessary to make an artificial tilth. It has the disadvantage that more than one pair of cattle are required to draw it, and unless it is very carefully adjusted the level surface of the land is destroyed. This is of importance in the tropics where rainfall is sufficient at times to start surface wash, and any irregularities in the surface will soon develop into temporary torrents which may cut deeply into the soil.

CARE OF THE YOUNG PLANTATION.

From the time that the young trees have been planted out there is constant work to be attended to. With the same rainy weather which made conditions suitable for planting, there will be a large crop of weeds to deal with. These will be much worse where the land was previously under grass or scrub jungle than where it was high forest. Annual weeds will grow with renewed vigour after the ploughing already given to the land and these should be dealt with as early as possible.

The growth of annual weeds in the tropics is very rapid and it is surprising how rapidly these get a hold on the land. Within three or four days of the appearance of these weeds as seedlings, they will have sent their roots down to a depth of several inches into the soil and are thus protected against the drying out of the surface soil, which may be very rapid under a hot tropical sun. When once weeds have become established their subsequent growth is very rapid and it takes much labour to get rid of them. It is essential therefore that these should be dealt with when they are quite small; and in order to deal with as large an area within as short a time as possible, the value of tillage implements as opposed to hand weeding cannot be too strongly emphasized.

The object of such cultivation is to cut the soil at a depth of some 2 or 3 inches below the surface. This will sever the roots which any weeds have made to establish themselves in the soil. If dry weather follows this operation, this loosened surface soil will rapidly dry out in the hot sun and the weeds will be killed before they have had time to re-establish themselves.

If soil conditions permit, the light cultivator is the best implement to use for this work. Where, however, the roots of previous vegetation have not yet decayed, it is difficult to work an implement which has a cutting edge and it may be necessary to cross plough with a plough set at a depth of 3 or 4 inches. When such a ploughing has been given and the surface has been levelled down by subsequent rain, it is then frequently possible to work the cultivator. Hand hoeing will, however, be necessary in either case in the immediate vicinity of the trees. These must on no account be allowed to get smothered by weeds.

Where there is a definite dry season, the whole area should be ploughed at the end of the rains and the surface levelled down with the cultivator immediately afterwards. This will form a soil mulch on the surface which will keep the moisture in the ground. Where there is no definite rainy season this work of cultivation must be done at regular intervals, taking advantage of any breaks of fine weather. Here the manager of the plantation must use his judgment as to when the operation is necessary.

Where the land which has been planted up was previously high forest, such a system of cultivation will be impossible till the stumps of forest trees have decayed away ;

but even here it is necessary to go in for much more cultivation than is usually done. The present practice is merely to weed the surface with the aid of manual labour. This is not enough. The fertility of the surface soil in such cases is great, and there is therefore a natural tendency for the roots of the coconut to come quite close to the surface. Not only is there this surface fertility, but there are large accumulations of humus, and this tends to keep the moisture in the surface layers of the soil. Thus the whole tendency of the root system of the coconut in such cases is to come to the surface, whereas this should be protected by a surface mulch which will keep these out of harm's way.

Digging by hand is usually looked upon as "weeding" and not as cultivation. This is a mistake. Such manual work should be at least 3 or 4 inches deep. This will destroy annual weeds. It will break down the excess humus in the surface soil. It will protect the roots from damage by drought and by the heat of the sun's rays. The better aeration of the soil will give the plants a deeper feeding-root system.

Some writers emphasize the necessity of humus in the soil, but under tropical conditions it is impossible to maintain this supply. It is of little use, therefore, accustoming the young trees to a rich humus soil when the organic matter present is bound to disappear to a large extent. It is much better to accustom the trees to a deeper root system which will make them accustomed to their permanent conditions.

Another important point with regard to this deeper cultivation is that the grubs of the rhinoceros beetle feed on decaying organic matter, and by turning up the soil to this depth these are exposed and can be destroyed.

A constant look-out should be kept for any of the perennial grass weeds which are likely to spread. Unless these are eradicated they will cause great expense later on; for in a cultivated soil they will spread much more rapidly than they would without cultivation. Some of these can be eradicated by constantly checking their surface growth, but others only seem to be encouraged by this process. Local conditions will soon teach one which is the cheapest method, whether it is better to eradicate by digging the weed right out, or to keep worrying at it by constantly removing the surface growth.

Periodic inspection of the plantation is necessary in order to see what damage is being done by insect pests. As already mentioned the rhinoceros beetle is liable to do great damage to the young plantation. This bores into the bud of the seedling just above ground level and when the seedling is young it very quickly reaches a vital part. Where this pest is bad it will pay to keep two or three smart boys who have been trained to look out for this attack, and who can go round the planted area at least twice a week to detect this damage. Though the young tree will receive a serious check it is often possible to save its life if the beetle has not actually destroyed the bud itself. The damage done by the beetle can be located by the debris of chewed tissue around the hole which has been bored into the young plant. If the beetle is still there it should be removed and destroyed. The fibrous stipules which bind the leaves round the young crown should then be cut and the leaves pressed to the ground on all sides. Unless this is done the young shoot when it has recovered will grow through the hole made by the beetle and will become deformed. If the young emerging leaf has also been eaten through this should be removed at the same time, as this very rapidly rots at the base and becomes a stinking mass of putrid vegetation. The newly-formed leaves as well as the shoot will take on a spiral habit of growth and it will be some considerable time before the growth again becomes normal, while there will always be a deformity at the base of the tree. Occasionally when a seedling has been attacked by this beetle, instead of forming fresh leaves the shoot develops a blunt horn-like structure. When this occurs the seedling must be replaced as the bud has ceased to grow and the tree will die.

Besides the rhinoceros beetle there are several other pests which it is necessary to look out for. Though many of these are not serious when they attack the grown tree, they may cause serious damage when they attack the seedling before it has reached the stage when it has commenced to form the split leaf. When the split leaf has been formed the damage will usually be confined to the single leaflet, but in the young seedling the damage will spread right across the whole leaf. Further, the rate at which the seedling forms fresh leaves is much slower than later on when the plant has become fully established. Thus any damage done takes much longer to repair, besides which the seedling is much reduced in vigour by the damage done.

All ants seen on young seedlings should be looked upon with suspicion. Though these do not as a rule do any direct damage, they have a habit of farming other sucking insects on the leaves of the coconut, which they tend and which they transplant to any succulent part of the seedling. They are largely, if not wholly, responsible for the spread of scale insects, meally bugs, &c. If ants are seen on the trees one may be fairly certain that there will be some other pest present—either scale or some other sucking insect. If these colonies are seen in time they can be destroyed by rubbing the leaf between the finger and thumb. This may obviate the necessity of spraying later on. Ants are not difficult to see. Very often their presence is noticed by their bringing up fresh soil round the base of the stem where they have built their nests in the soil. They are specially noticeable after rain when they are very busy clearing the soil which has been washed into their nests. There is a small red ant which may cause direct damage. This frequently makes its way into the seed nut, and when it does, the "apple" and any of the reserve endosperm still inside the nut immediately go rotten. This frequently causes the death of the seedling and in any case causes a serious check in its growth, since the young plant is then entirely dependent on its own root system for its sustenance.

Anyone who has had any experience with the old-world tropics is familiar with the large red ant (*Œcophylla smaragdina*), which builds its nest by weaving together the leaves of the tree or shrub on which it is, and which will immediately attack anyone who disturbs it. This ant may prove a serious pest, since it lives on the sweet juice exuded by a meally bug which it farms on the coconut tree. This meally bug seriously weakens the tree. Nests of these ants are common on young plantations established on land which was previously under high forest.

Among other pests which damage the young plant may be mentioned the "bag" worm and the caterpillar of the coconut "skipper" butterfly. It is not so much the amount of leaf surface which these eat as the fact that they eat right across the leaf, and thus may reduce the size of the leaf to half.

The young seedling, when at the critical stage when the food supply in the "apple" is exhausted and before the "cabbage" is developed, is very susceptible to the attack of the leaf disease caused by the fungus *Pestalozzia palmarum*. Instead of forming small spots on the leaf surface, as it does when it attacks the leaf of the grown tree, this fungus causes large diseased blotches which spread right across the surface of the leaf and from which infection is carried to the tip of the next forming leaf. If the attack is severe, the diseased portion of the leaves should be cut off and burnt. The trees should then be sprayed with a Bordeaux-resin-soda mixture. The ordinary "Bordeaux mixture" without the resin is of little use, as this will not stick to the smooth surface of the coconut leaf.

CATCH CROPS.

It must always be borne in mind that the coconut is the primary consideration, and this being the case, anything which will retard its growth and delay the time when the crop comes into bearing must be looked upon with suspicion, if not actually with disfavour. Catch crops interfere with cultivation: they interfere with weeding, and often make this much more expensive than it would otherwise be. They are also able to detract both labour and supervision from the coconut.

There are circumstances, however, when the cultivation of other crops besides the coconut may prove to be essential. It may be that the capital is insufficient to pay for the labour till revenue commences to come in from the coconut. It may be necessary to find work for the labour at slack seasons: this may be the case where labour has to be imported from a distance and it is essential to retain it. It may be necessary to grow food to feed the labour as well as the cattle, or it may prove an economy to grow this on the estate. In the Federated Malay States recent legislation has made it compulsory for every estate to grow a certain portion of the area with food crops on account of the uncertainty of food supplies from outside.

It does not necessarily follow, however, that these crops should be grown on land planted up with coconuts, and it will often prove more economical, both of land and labour, to set apart land specially for the cultivation of other crops. As a permanent proposition there is no doubt that the second alternative is to be preferred. In the moist tropical climate which suits the coconut and under ordinary conditions of farming, it is very often possible to grow two crops a year on the same land, and thus the area set apart for such crops will not be so great as one would at first sight imagine. It is also possible often to utilize land for this purpose which is unsuitable for the coconut. For example, low-lying land into which the drainage of the estate falls can possibly be converted into rice land, and frequently two crops a year can be obtained from this, which not only provides food for labour, but straw for the cattle.

Among petty cultivators, one sees a variety of crops grown in coconut gardens, and in countries where the population is dense and the pressure on the area under cultivation is great, these have often, of necessity, to be grown. Among grain crops, dry land rice and raggi (*Eleusine coracana*) are most common. Dry land rice is not so good a crop as raggi since the seed has to be sown *in situ* and it is impossible to do any efficient weeding. On the other hand, raggi can be sown in a separate seed bed and subsequently transplanted, thus leaving ample space between the plants to render weeding feasible. These two are possibly the least exhaustive cereal crops which can be grown.

Among pulses there are several bush varieties of cow pea (*Vigna catyang*) which grow very well under the shade of coconuts. These are often grown by native cultivators mixed with raggi. Sometimes they are grown as a pure crop round the base of the trees, and after the pods have been gathered the plant is dug in as a green dressing. Where there is a definite dry season and the soil is not too fertile, horse gram (*Dolichos uniflorus*) is often grown in the dry season. This furnishes a pulse which can be used either as food for man or for draught cattle. The objection to this as a catch crop is, however, that it is a dry weather crop and at that time a soil mulch should be preserved for retaining the soil moisture for the benefit of the coconut.

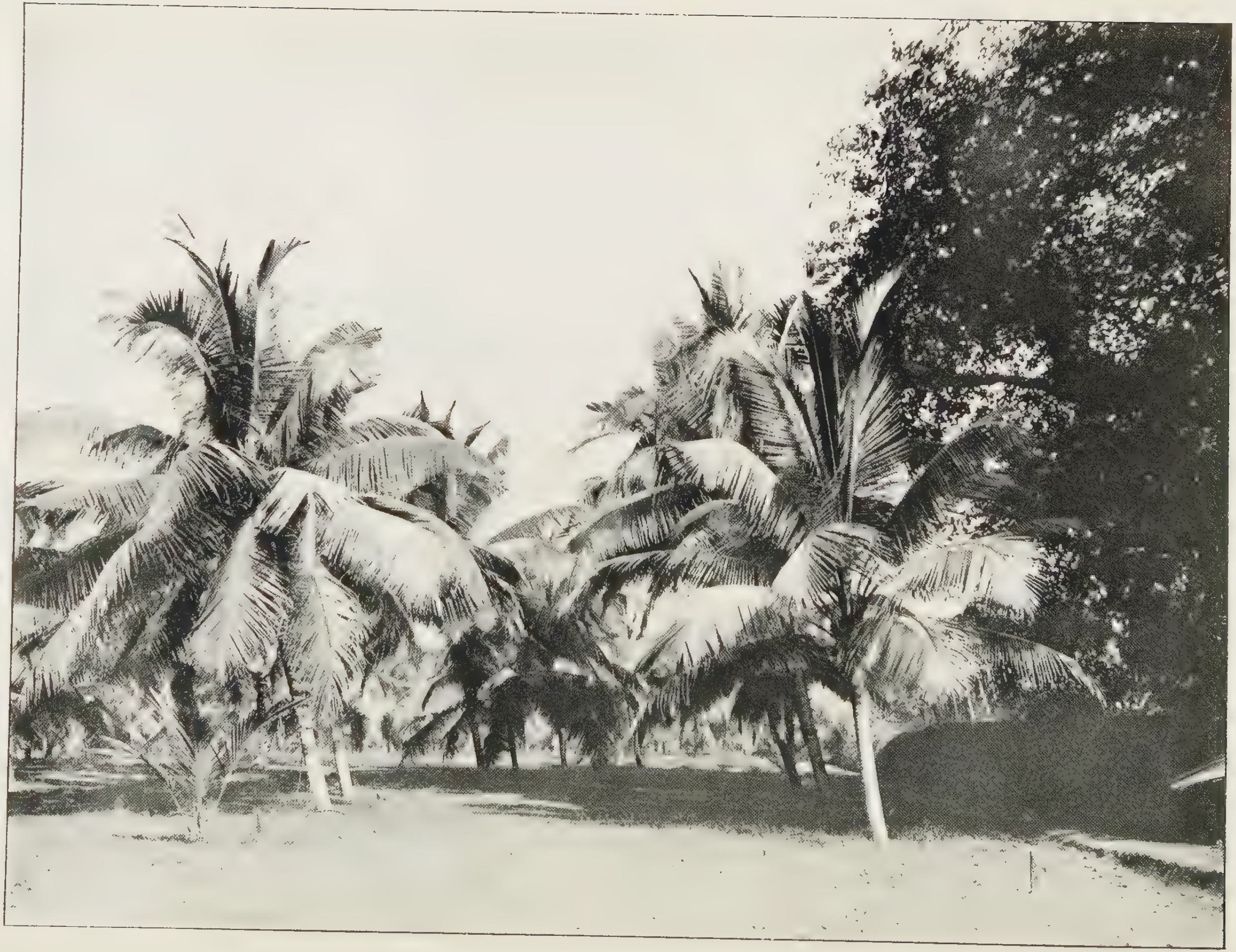
Pulses are much less objectionable than cereals when planted between coconuts, since they are what are termed soil recuperative crops. They also furnish a substitute for meat for the labour force which is often difficult to cater for otherwise. They furnish a much better cover than do cereals and are thus much more serviceable in keeping weeds in check.

Every native grower invariably has some root crops planted among his coconuts. Various yams and colocasias are grown for domestic consumption, and manihot (tapioca) as well as the sweet potato may be grown on a larger scale for sale. Tapioca is a favourite crop for this purpose and requires little attention after the cuttings have once been planted. On a fertile soil also the plant will form a fairly efficient cover for the suppression of weeds. It has a reputation of being an exhaustive crop, though whether this is due to the amount of plant food which it takes from the soil, or whether the tapioca has a toxic action and thus affects the growth of other plants is not known. It certainly has the effect of checking the growth of the permanent crop among which it is grown. There are varieties of this which take either six months or one year to mature their crop.

Sweet potatoes may prove of use for local consumption, or for sale if a market can be found for them. This very soon spreads and forms a ground cover, and thus may form a valuable crop for the suppression of weeds. In some places, also, it is said to form a protection to the young coconut plantation against rats when these visit an estate in hordes, as the rats prefer these tubers to the coconut seedlings. Where the crop is to be lifted the work entailed gives the land a very efficient cultivation. The main objection to the sweet potato as a crop within a plantation is that, when it is once established, it is very difficult to eradicate, as any small piece of the tuber or of the vine, if covered by the soil, will grow.

Where rice is the main diet of the labour force, it is always as well to set apart a small area for the cultivation of green vegetables. It is essential that these should form a part of the diet of the labourers if they are to remain healthy and free from such diseases as "beriberi," scrofula, scurvy, &c. In most cases the labourers themselves are skilled in the growth of such vegetables. These will include varieties of marrows, pumpkins and gourds, amaranthus, and, if it is Indian labour, it will also include chillies and turmeric.

Among other catch crops grown as a plantation crop, coffee (*Cafea robusta*) is sometimes recommended, but it is very doubtful if it is ever worth the trouble. It can only be profitable for a very short period if the growth and development of the coconut is at all normal, and a glance at Plate II



Coconut trees reaching out to the light from the shade of a banyan tree will show that at a very early stage in the growth of the coconut the roots of any other tree must enter into direct competition and this will check the growth of both.

Some attempts have been made to grow coconuts and rubber together, but always with disastrous results to both crops. Both these are what are known as "light demanders" and neither can stand being grown in the shade. Thus whichever overtops the other spoils all chance of the tree, which has thus been suppressed, from ever doing any good.

As regards other trees which are frequently grown in coconut gardens by native growers, such as the mango and the jack, these should never be allowed. The two trees mentioned are specially objectionable as they both throw a very heavy shade, and if ever they are allowed to overtop the coconut the prospect of any crop from the latter is gone. The effect of shade on the growth of the coconut is clearly shown in Plate XXVII where these can be seen leaning away from the shade of a neighbouring banyan tree.

COVER CROPS.

Opinions vary as to the uses and value of cover crops. The uses claimed by the cover crop may be enumerated as follows :—

(1) By covering the surface they keep down the growth of weeds, and will even at times eradicate such weeds as imperata grass.

(2) By covering the ground they prevent surface wash.

(3) By covering the ground they check the loss of soil moisture by evaporation.

(4) When they are ploughed in they add humus to the soil.

(5) If they belong to the family of the Leguminosæ, they can fix the nitrogen of the air, and this can be rendered available to the coconut when the cover crop is ploughed in.

The first two of these claims can be accepted. A good cover crop, growing close to the ground, may very effectively keep down dangerous weeds. This may be of decided use on a coconut estate. The growth of weeds is more or less seasonal and the work of weeding comes on with a rush, so that often it may be found difficult to obtain labour to cope with it. By having a portion of the estate thus temporarily protected by a cover crop, the period of weeding can be spread over a longer time.

A cover crop on undulating ground will be of use in preventing surface wash provided this has not already been protected by terracing, If this has been done then the surface wash should primarily be utilized for levelling the terraces.

As a protection against the loss of soil moisture there is nothing to justify this claim. It is well known that a surface of vegetation loses much more moisture from transpiration from the leaf surface than will a soil surface unprotected in this way, even without a soil mulch. Certainly the soil looks moister under a cover crop, but this is because the sun's rays do not reach the soil surface. During the cloudy weather of the rainy season transpiration is reduced, and this coupled with the checking of surface wash may allow more water to penetrate the soil, but this is often a time when more water in the soil is not required.

There is no doubt that when a cover crop is ploughed in it does add humus to the soil and that, if the cover crop is a legume, it does add nitrogen to the soil as well, but, whether this humus is required by a crop such as the coconut which should have its feeding roots mainly in the upper 3 feet of the soil and not right at the surface as is usually the case with an annual crop, is a matter of opinion, and in that of the writer the addition of humus is not required except on coarse coast sandy soil where something is necessary to hold the soil together. As regards the addition of fixed nitrogen to the soil by the aid of a cover crop, it has yet to be proved that this is as valuable as that added by soil bacteria, which are very active when the surface soil is kept well aerated by means of cultivation. Recent research also has shown that large quantities of the nitrogen which is contained in a leguminous cover crop, is utilized by those soil bacteria which break down the cellulose in the ploughed-in crop, and that these may even rob the soil of what nitrogen it had in order to carry on their work.

On light soils in the tropics, it is doubtful whether a cover crop is ever of any use to a crop such as the coconut. A cover crop makes heavy demands on the soil moisture and when this occurs it is at a season when the coconut itself needs it more. In a light soil the roots of the cover crop are not confined to the surface soil, and as such light soils are not as a rule too well supplied with plant food, it means that the coconut has to compete with the cover crop for this and suffers in consequence. It is true that the coconut would get this when the cover crop was ploughed in, but it does not do for a tree such as this to grow by fits and starts in this way. Even if the cover crop were of value on such land, it is often difficult to get a full stand and cover, since growth is slow on a soil which is not too fertile, and thus much of its value as a protection against weeds is lost.

On heavier classes of land a cover crop may have its uses. Here often the upper layers of soil are already too damp and the cover crop aids in getting rid of the excess moisture and thus improves the drainage and aeration of the soil. A heavy soil also is usually much more fertile and therefore the stand of the cover crop will be much more complete. In such cases it may prove decidedly useful for getting rid of weeds or at any rate in keeping them in check.

What is required for a cover crop is some plant which will form a complete cover and will not at the same time smother the plantation crop either by growing too tall or by growing over it. It must be able to withstand the partial shade of the plantation as well as the drip off the leaves during heavy tropical rain. It is advisable, also, to take care not to get a plant which seeds too freely as this may become a pest or weed if conditions suit it. As an example of such an introduction may be instanced that of the "sensitive plant" into the Federated Malay States. Though in many respects this is an admirable cover crop, it has the objection that it is thorny and that labourers with bare feet cannot work where this is growing. It has the further disadvantage that it seeds very freely, and under such suitable conditions for its growth as the Federated Malay States provide, its spread cannot now be prevented.

The type of cover crop for a crop like the coconut is very different, for example, to what is required by a crop such as tea. *Tephrosia candida* is an excellent crop to grow between tea since this can be cut back and the cuttings buried between the lines of the tea bushes. Tea also has a deep tap root and is therefore not so dependent on the moisture in the upper layers of the soil as is the coconut, which in dry weather would feel the competition for soil moisture, which there would be if a closely-planted erect cover crop such as this Tephrosia were grown. The same applies to a cover crop such as *Crotolaria striata* or *Cajanus indicus*. The most suitable type of cover crop is one that spreads along the ground. Here the plants need not be too close together, since their habit causes them to form a complete cover to the ground even though the plants may be 3 or 4 feet apart. What this crop should be depends on local conditions. In the Federated Malay States the most suitable cover crop for coconuts appears to be *Centrosema plumerii.* The only precaution which has to be taken is to see that this does not grow over the coconut. In a grown plantation there is no fear of this as the creeper will not climb the stem of the tree.

In the Philippines preference, it is stated, is given to *Phaseolus lunatus* as a cover crop, while in other countries the velvet bean (*Mucuna utilis*) is recommended. The sweet potato and the cow pea have already been mentioned as suitable for cover crops as well as catch crops.

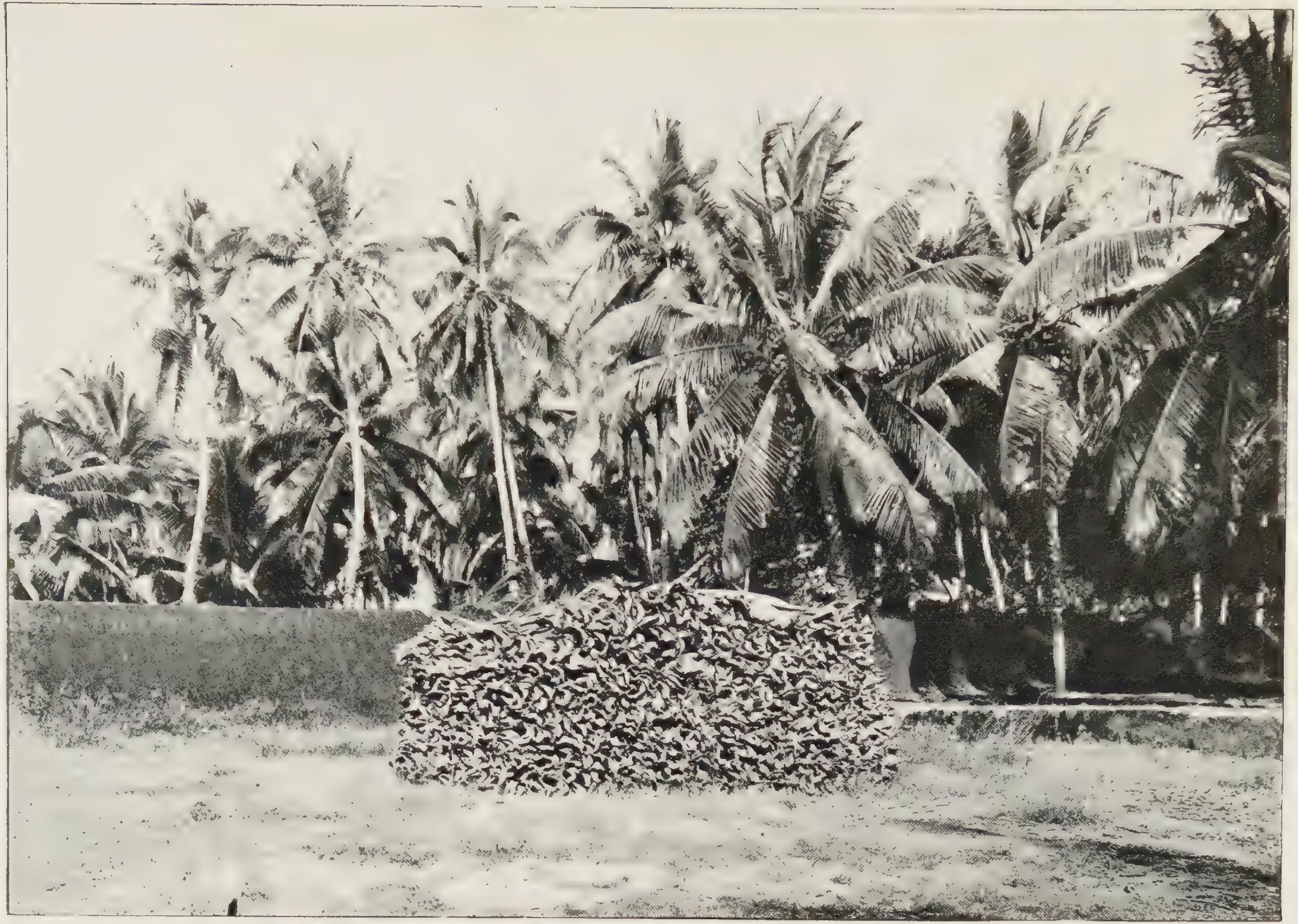
MANAGEMENT OF THE GROWN PLANTATION.

As far as cultivation is concerned there is very little difference in the management of a grown plantation to that of a young one. If there is a definite rainy season cultivation consists of ploughing at the commencement of this and again at its close and of subsequently working the cultivator as often as is necessary in order to preserve a soil mulch. The objects of cultivation have already been discussed and need not, therefore, be dealt with in detail again here.

During the rainy season a watch should be kept for any signs of surface wash. Even where the land surface appears quite level to the eye, it will usually have a slight fall in one direction or another, and heavy tropical rainfall will soon scour out for itself some way for the water to run off the surface. If this occurs it must be immediately checked by making earthen "bunds" or walls along the line of the contour. In making these the earth should always be taken from the lower side of the bund so that any further wash may level up the land above the wall.

Besides cultivation there is much work to do in keeping the plantation clean. Leaves are constantly falling and the dead spathes from the trees have to be disposed of, otherwise they are a great hindrance to the work of cultivation. The methods of disposal vary much with the local conditions. In densely populated countries there is always a sale for such bye-products. The butt of the leaf is always saleable as fuel, and these are stacked for fuel as shown in Plate XXVIII. These are either used for domestic purposes or for local industries such as lime burning, &c. Occasionally they are used as temporary fencing posts. In such countries the leaf proper, except for the tip which is cut off, is used for making "cadjans" or leaf mats. Each leaf makes two of these. The midrib of the leaf is split along its length and the attached leaflets on the one side of the half leaf stalk are plaited into a mat. Such work is usually done by women and affords them occupation during times when outdoor work is slack. These leaf mats are used for thatching buildings, for building temporary sheds, for various purposes such as tobacco and fish-curing sheds, for temporary erections connected with wedding ceremonies, &c. The sale of such bye-products brings in an appreciable income in densely populated countries, and where the house ashes can be returned to the plantation there is very little loss of plant food, but where the cultivation of coconuts is carried on in a large scale such a method of disposal is out of the question, except for the limited demands of the estate itself. The only other methods of disposing of this material is either by burning or burying it. Where the soil is inclined to be heavy and the natural drainage of the land requires improvement, a good deal of this material can be disposed of by burying. Under such circumstances cultivation should aim at throwing surface water away from the stem of the tree. Ploughing should throw the soil up from each side to the line of trees which follows the general contour of the land. This as time goes on will form wide ridges and furrows with

PLATE XXVIII.



The butt ends of coconut leaves stacked for sale as fuel.

the line of trees along the ridge. Drainage can still further be improved by digging along the furrow thus formed between the two lines of trees and filling this with fallen leaves, &c. This can then be covered over with the soil removed from the drain. Leaf debris can also be buried along the crest of the ridge which will emphasize this. Such dry and dead debris can safely be buried as it is too dry and fibrous to attract the rhinoceros beetle. Where the soil is sufficiently open not to require any artificial aids to drainage, all such debris of the tree should be burnt in small heaps along the line between two rows of trees, and the ashes after burning should be spread over the surface of the ground. Great care is necessary when such material is burnt to see that the stuff does not burst into flame as there is always a danger that the flames may set on fire the leaves of the trees, and this causes serious harm to the palm which cannot repair the damage till fresh leaves are formed, and as these are only formed at the rate of one in about twenty-five days it can be readily understood that a considerable time must elapse before the damage is rectified. Burning refuse should always be carefully supervised and a few green leaves should always be at hand to damp down the fire when it is seen that there is a danger of its bursting into flame.

It may be that in time some use may be found for the fibre which is in this debris. There is a strong coarse fibre in the leaf stalk. There is a very fine brush fibre in the fruit branch stalk, and there is a very strong fine fibre in the inner spathe any of which may prove to be worth extracting.

HARVESTING.

When the plantation is first laid out it is as well to have an idea of the routine of harvesting and what products of the coconut it is intended to dispose of. Questions which have to be answered are: in what form is the produce to be sold?—is it to be made into oil on the estate or is the produce to be sold as copra?—is any attempt to be made to deal with the fibre in the husk? The answers to these questions will decide whether to work the estate on the system of a central factory or whether to work the estate in separate small blocks. Where copra is decided on as the method of disposing of the produce and no attention is to be given to the manufacture of coir fibre, the small block system is undoubtedly the best, and provision should be made for dealing with the crop in separate blocks of not more than 150 acres each. Each block should then be divided up into small sections of about twenty acres centreing round the place where the copra is to be made. Each such section should be provided with an open space where the nuts harvested in that section can be husked. This will reduce the weight and the bulk of stuff which has to be conveyed to the drying place. At each such open space where the nuts are to be husked, a furnace should be made where the husks can be burned, and alongside of this should be built an ash house. The husk of the nut is very rich in potash and this is required in large quantities by the coconut, and therefore all of this should be returned to the land. The situation of this open space for husking nuts should be so located that it is within easy reach of the road, canal or tram-line which is to convey the husked nuts to the drying place. Similarly the drying places should be within easy reach of the main stores where the copra is to be stored till it is removed from the estate.

There should be a regular programme worked out for harvesting. This, in the first instance, will have to be based on local experience as to what seasons of the year give the heaviest crops. If harvesting is to be done at intervals of say three months, it may be found that at certain times of the year this interval will have to be shortened to once every two months, while at other times it may be lengthened out to every four months.

As to the right time for harvesting nuts, this has been dealt with on p. 70. If there is any doubt in the matter, it is best to err on the side of under rather than over-ripeness. When the nuts have been picked they can always be kept for some days heaped on the ground, where they will continue to ripen in the same way that corn in the stook will ripen up in the field.

The great danger of leaving the nuts on the tree till they appear to be dead ripe is that they will frequently commence to germinate on the tree or on the ground where many of them will inevitably fall before they can be collected.

As to the method of picking, this will depend on the height of the trees and the kind of labour employed. Where labour is accustomed to climb trees, or where it can be trained to do so, there is no doubt that this is the most satisfactory method of harvesting.

Any labour recruited from Southern India will always be able to climb the trees, though if any difficulty is experienced in getting skilled climbers, men belonging to the toddy-tapping castes can always be recruited. These are the Shanars of the East coast and the Tiyas of the Malabar coast. Climbing palms is part of their hereditary occupation, and all those recruited from the rural districts are skilled climbers. The actual method of climbing the trees varies in different places. The climber is equipped with a short ladder some 8 or 9 feet high, which he plants against the bole of the tree which he is going to climb. He mounts to the top of this and then places a ring of rope over one foot across the instep. The other foot is then placed in the ring in the same way. This ring is of such a size that when stretched in this position with the heels close together the stem of the tree is clasped with the inside arch of the feet. In many parts the climber has another rope ring for the hands. This goes over the back of the hand, between the thumb and the fingers along the palm. This helps him to clasp the stem of the tree with his hands and arms and may be considered a necessary precaution, especially when the stem is wet and slippery. In other parts only one hand goes round the tree and the other is placed on the trunk on the same side as the climber with the fingers pointing downwards.

In order to mount the tree, the climber raises his arms as high as possible and grips the stem with his forearms, at the same time bending the arms at the elbows. He hangs in this way while he loosens his hold with his feet. These in their turn are then raised by bending the legs at the thigh and the knee while the feet again clasp the stem higher up. The climber then straightens his legs and arms, thus leaning right out from the tree. He then pulls himself into the tree again, and at the same time slips his arms up the tree and again repeats the process. Most of the effort tells on the arms and chest, and a climber can always be recognized by the development of the muscles on the shoulder and breast.

The most difficult part of the climbing is to get on to the crown of the tree. This is especially difficult when the tree is bearing a heavy crop of nuts, as the climber has to lean right out past the bunches of fruit in order to swing himself on to the crown of the tree. A certain amount of judgment also is required as to which leaves to cling to when swinging the body up, as the lower leaves are liable to give way with the extra weight of the climber. The band round the body, which is sometimes described as being used by climbers, is not used in the case of the coconut. It is intended for climbing the palmyra, where the leaves are too slender to carry a man's weight; nor is it advisable to furnish climbers with this as one of the main advantages of climbing the trees for the harvest of nuts is that a careful watch can be kept for the attack of the rhinoceros beetle, and this attack can only be seen in time to prevent serious damage if the climber actually mounts the crown of the tree. These beetles seem to emerge from the pupal stage all at about the same time, and if the beetle is seen in large numbers, a systematic search throughout the plantation must be made there and then.

The climber when he is up the tree can, with very little training, easily tell which is the ripest bunch on the tree. He can also be taught where to look for the next ripest bunch, and by tapping this with his nail ascertain whether the nuts on this are ready for cutting. The usual method is to cut the stalk of the fruit bunch, and thus allow the whole bunch to fall to the ground. The number of bunches cut from one tree at any one harvest will vary with the season of the year. During the main harvest season three and even four bunches may be cut, while during the off season only one bunch may be ready for harvesting.

A man can climb from eighty to a hundred trees a day according to the height of the crown from the ground. Where labour is unable or cannot be trained to climb the trees, the nuts will either have to be cut from the ground or allowed to fall of themselves when they are ripe. The former method is much the more preferable if it is feasible, though it may be difficult if the trees are very tall. The objection to allowing the nuts to fall of themselves is that there is always a probability that a proportion of these have already commenced to germinate. As has already been pointed out this means that not only will the quality of the copra be poor, but a considerable quantity of the oil will be lost, as the process of germination causes the oil cells in the meat to break down.

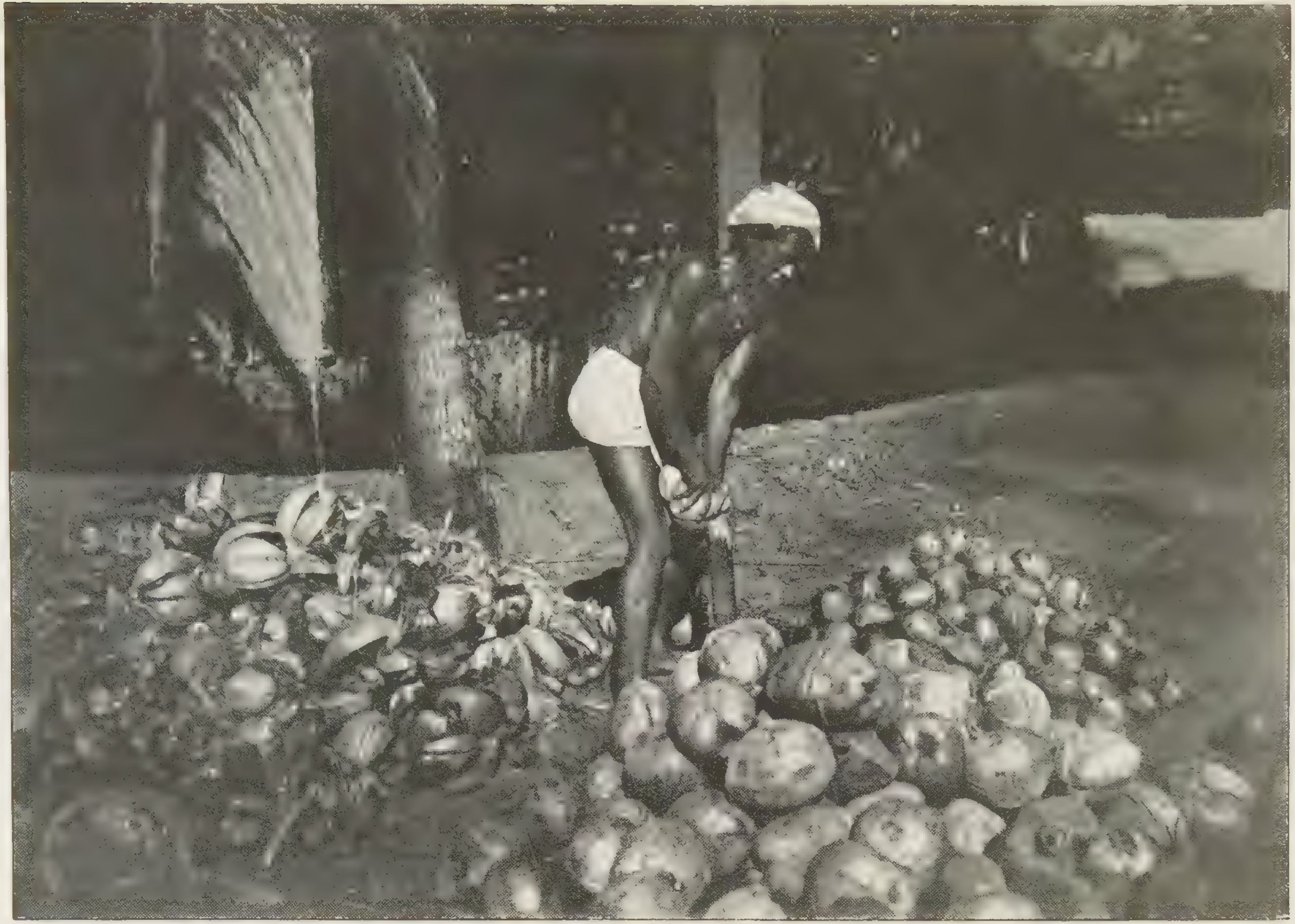
The usual method of harvesting from the ground is to tie a hooked knife at the end of a light bamboo pole. The hook of the knife is placed over the fruit branch and a sharp jerk severs this from the tree, causing the bunch to fall. Some prefer to cut each nut on the bunch separately, but this is a waste of time. Where nuts are allowed to fall of their own accord, a collection of these from the ground must be done at much shorter intervals than if they are cut from the tree. Under such conditions the nuts are dead ripe, and lying on the damp ground will soon commence to germinate, if they have not already commenced to do so.

Local conditions will decide the best means of conveying the harvested nuts from the field to where they are to be husked. Where the drains run, or where they contain water, water carriage is the cheapest and simplest. If there is a flow of water the nuts can simply be thrown into the drains and the current will carry them down-stream. Where the flow is insufficient they can be towed down. The usual method of towing them is to tie two nuts together by strips of the rind and to sling them over a rope. Two other nuts are similarly tied and are slung across the first two. This process is repeated till the rope will not hold any more, when it is towed down to where the nuts are to be husked. Where nuts are grown close to tidal lagoons, these are thrown into the water and are then collected into boats and thus conveyed to where they are to be husked. Where there are no facilities for water transport, the nuts will have to be carried. Usually large open-work rattan baskets are employed for this, which are either carried as head loads, or two are balanced on a pole across the shoulders. The method adopted will vary with the labour employed. Tamil labour will only carry as head loads. Telugu as well as Chinese labour will carry two baskets balanced on a pole.

Female labour can often be employed for this work, as it is used to carrying headloads. From the husking centre to the dryer the husked nuts will have to be carted, either by tram-line, bullock cart or mechanical transport, whichever is found to be the cheapest and most efficient.

The task of husking the nuts is not expensive, and an average day's work for a man is about 1,000 nuts a day, though many experienced men on piece work will do 1,500 a day, and occasionally 2,000. The implement used for husking consists of a flattened spike. This is driven vertically into the ground with the spike uppermost, so that the point of this is about two and a half feet above the ground surface. The spike is either made of iron or it may be made of wood. In India this is often made of the wood of the arecanut palm. The fruit is then taken in both hands with one of the angles of the fruit uppermost, and the point of the attachment of the fruit to the fruit branch away from the operator and pointing slightly upwards. The operator faces the edge of the spike and brings the nut down on to it. This pierces the husk and glances off the round end of the nut where the eyes are situated. Plate XXIX. The fruit is then given a twist to one side which loosens the husk from the nut from one third of the fruit. The same procedure is adopted again on the face of the nut next to that which has been loosened, and a downward twist loosens the next segment of the husk. The third segment of the husk is by this time partially loosened, and can be removed by the hand. The beard at the "eye" end of the nut is then taken off by hand, leaving the clean fruit. The whole operation takes from twenty to thirty seconds according to the skill of the operator.

PLATE XXIX.



Husking coconuts.

In some countries husking is not done. The fruit is merely split with an axe and the meat gouged out in pieces. This entails that the whole, instead of the husked, fruit have to be conveyed to where the dryer is situated. If also the ash is to be used for manure, this will all be to carry back to the field. Copra made in this way is never so clean as when the nut is husked, and this detracts from its appearance and the price which is paid for it. It certainly is no economy in any country where sun drying of copra is possible, since the labour involved in gouging out the meat is much more than that required in husking and splitting the nuts and laying the half nuts in the sun to dry.

MANURING.

The idea underlying manuring is to supply the crop with sufficient plant food in the soil to enable it to maintain itself in a healthy condition and at the same time to produce, not necessarily the maximum yield, but the maximum profit. These are two very different things. If we get back to the derivation of the word "manure," we get at its correct meaning. This is the same as the word "manœuvre," which, according to the dictionary, means to "manage adroitly." The same idea is still conveyed in the dialect of the North-Riding of Yorkshire, where the word "management" is used for manure.

The coconut tree offers, perhaps, more scope for the investigation of the food requirements of a plant than any other. The development of new leaves, new fruit branches, and new fruit takes place at such regular intervals, and the fruit take such a long time to mature, that it is possible to take samples for analysis at definite stages in the development of the part required. It is thus possible to trace the movements of the various elements of plant food taken from the soil and used in the process of building up the various parts of the plant.

The following tables relate to the development of the fruit of a single tree. Three nuts have been taken from each bunch of a regular bearing tree, and the results of the analyses have been arranged in the order in which the bunches were formed on the tree, the oldest being placed first. These are the common copra variety of coconuts of the Malabar coast, and as regards the size of the individual nuts they are small in comparison with those of many other countries. The soil on which the tree was grown was a red sandy loam of no great fertility, and had not been manured for many years previously. It may be said, therefore, that the tree was forming fruit with about the minimum amount of plant food necessary.

The Actual Weight of the Whole Nut freshly picked and of the Several Parts. Three Nuts (*a*, *b* and *c*) from Each Bunch.

No. of the bunch (the number in brackets shows the number of nuts on each)		Weight of whole nut including husk grm.	Weight of husk grm.	Weight of shell grm.	Weight of meat grm.	Weight of water grm.
16 (15)	*a*	865	316	148	302	99
	b	878	346	139	288	105
	c	875	326	148	303	98
Mean of *a*, *b*, *c*		**873**	**329**	**145**	**298**	**101**
15 (11)	*a*	910	336	143	296	135
	b	920	350	148	294	128
	c	910	312	151	331	116
Mean of *a*, *b*, *c*		**913**	**333**	**147**	**307**	**126**
14 (7)	*a*	1,007	478	141	279	109
	b	775	410	117	198	50
	c	1,134	569	152	285	128
Mean of *a*, *b*, *c*		**972**	**486**	**137**	**254**	**96**
13 (16)	*a*	955	503	124	231	97
	b	885	473	120	213	79
	c	840	441	116	199	84
Mean of *a*, *b*, *c*		**893**	**472**	**120**	**214**	**87**

THE ACTUAL WEIGHT OF THE WHOLE NUT FRESHLY PICKED AND OF THE SEVERAL PARTS. THREE NUTS (*a*, *b* AND *c*) FROM EACH BUNCH.

No. of the bunch (the number in brackets shows the number of nuts on each)	Weight of whole nut including husk grm.	Weight of husk grm.	Weight of shell grm.	Weight of meat grm.	Weight of water grm.
12 (13) *a*...	941	505	123	219	94
b...	1,075	623	123	231	98
c...	960	496	127	225	113
Mean of *a*, *b*, *c*	**992**	**541**	**124**	**225**	**102**
11 (4) *a*...	1,315	789	142	208	176
b...	1,083	836	132	115	—[1]
c...	946	743	133	70	—[1]
Mean of *a*, *b*, *c*	—	—	—	—	—
10 (6) *a*...	1,255	760	124	174	197
b...	1,230	754	117	155	204
c...	1,400	867	133	184	216
Mean of *a*, *b*, *c*	**1,295**	**794**	**125**	**171**	**206**
9 (3) *a*...	1,422	914	226[2]		282
b...	1,342	860	230		152
c...	1,235	740	234		261
Mean of *a*, *b*, *c*	**1,333**	**838**	**230**		**232**
8 (3) *a*...	1,262	835	150		270
b...	1,237	857	151		229
c...	1,305	830	114		361
Mean of *a*, *b*, *c*	**1,268**	**841**	**138**		**289**
7 (6) *a*...	1,100	827[3]			273
b...	965	707			258
c...	1,022	767			255
Mean of *a*, *b*, *c*	**1,029**	**767**			**262**
6 (7) *a*, *b* and *c*	1,360[4]				
5 (6) *a*, *b* and *c*	965				
4 (5) *a*, *b* and *c*	255				
3 (12) *a*, *b* and *c*	95				
2 (5) *a*, *b* and *c*	50				
1 (13) *a*, *b* and *c*	6·2				

[1] Fruit in these not properly developed.

[2] Shell and meat sampled together.

[3] Husk, shell and meat sampled together.

[4] Whole fruit sampled.

ANALYSIS OF THE DIFFERENT PARTS OF THE COCONUT FRUIT AT DIFFERENT STAGES OF GROWTH.

No. of the bunch and part of the fruit analysed (figures in brackets indicate the number of nuts in the bunch)	Moisture Per cent.	Nitrogen Per cent.	Phosphoric acid Per cent.	Potash Per cent.	Lime Per cent.	Magnesia Per cent.
		(In dry matter)				
Bunch No. 16 (15)						
Husk	16·45	0·44	0·066	1.11	0·34	0·21
Shell	17·54	0·38	0·013	0·14	0·091	0·014
Meat	43·46	3·05	0·46	0·80	trace	0·16
Water	95·04	0·50	0·56	6·60	0·69	0·51
Bunch No. 15 (11)						
Husk	18·99	0·40	0·09	1·03	0·32	0·21
Shell	17·10	0·40	0·015	0·12	0·045	0·016
Meat	45·63	2·77	0·43	0·82	trace	0·16
Water	96·58	0·57	0·76	10·11	1·22	0·82
Bunch No. 14 (7)						
Husk	40·57	0·58	0·059	1·02	0·44	0·22
Shell	17·00	0·34	0·012	0·11	0·086	0·016
Meat	46·04	1·09	0·45	0·75	trace	0·14
Water	94·92	0·28	0·45	6·12	0·61	0·45
Bunch No. 13 (16)						
Husk	46·70	0·22	0·074	1·09	0·28	0·18
Shell	17·00	0·30	0·024	0·24	0·19	0·021
Meat	48·33	1·14	0·50	0·86	trace	0·17
Water	95·64	0·32	0·44	5·78	0·68	0·41
Bunch No. 12 (13)						
Husk	56·34	0·38	0·10	1·24	0·13	0·14
Shell	18·50	0·34	0·020	0·33	0·14	0·010
Meat	55·86	1·33	0·52	1·28	trace	0·27
Water	94·78	0·40	0·26	4·55	0·52	0·43
Bunch No. 11 (4)						
Husk	68·06	0·43	0·083	0·87	0·24	0·20
Shell	21·30	0·35	0·029	0·27	0·17	0·022
Meat	64·47	1·39	0·58	1·91	trace	0·23
Water	96·60	0·47	0·55	6·68	0·92	0·73
Bunch No. 10 (6)						
Husk	75·97	0·50	0·11	1·05	0·33	0·27
Shell	27·32	0·37	0·043	0·18	0·13	0·019
Meat	74·55	1·49	0·56	1·78	trace	0·23
Water	95·40	0·59	0·48	6·26	0·71	0·58
Bunch No. 9 (3)						
Husk	77·62	0·45	0·11	0·90	0·48	0·28
Shell and meat...	56·01	0·78	0·17	0·74	0·17	0·16
Water	95·40	0·50	0·51	3·81	0·63	0·67
Bunch No. 8 (3)						
Husk	81·58	0·56	0·13	0·92	0·34	0·30
Shell and meat...	61·00	0·84	0·18	0·69	0·30	0·17
Water	96·08	0·46	0·50	3·71	0·64	0·76
Bunch No. 7 (6) ...						
Husk, shell and meat	80·54	0·82	0·17	1·02	0·22	0·31
Water	95·37	0·41	0·50	2·82	0·70	0·62
Bunch No. 6 (7)						
Whole fruits ...	82·91	0·85	0·21	1·33	0·39	0·39
Bunch No. 5 (6)						
Whole fruits ...	83·24	0·80	0·23	1·49	0·33	0·35
Bunches Nos. 4-1 (35)						
Whole fruits ...	75·72	0·87	0·28	1·88	0·34	0·35

DRY MATTER.

Quantity Present in One Nut from Each Bunch.

No. of the bunch (figures in brackets indicate number of nuts in the bunch)	Husk Grm.	Shell Grm.	Meat Grm.	Water Grm.	Total Grm.	Husk Per cent.	Shell Per cent.	Meat Per cent.	Water Per cent.	Total
16 (15)	274·9	119·6	168·5	5·0	568·0	48·4	21·1	29·6	0·9	100·0
15 (11)	303·0	121·9	166·9	4·2	596·0	50·8	20·5	28·0	0·6	100·0
14 (7)	288·8	113·7	137·1	4·9	544·5	53·0	20·9	25·2	0·9	100·0
13 (16)	251·6	99·6	110·6	3·8	465·6	54·0	21·4	23·8	0·8	100·0
12 (13)	236·2	101·1	99·3	5·3	441·9	53·3	22·9	22·5	1·2	99·9
11 (4)	252·0	111·8	73·9	6·0	443·7	56·8	25·2	16·6	1·4	100·0
10 (6)	190·8	90·9	43·5	9·5	334·7	57·0	27·2	13·0	2·8	100·0
9 (3)	187·5	101·2		10·7	299·4	62·6	33·8		3·6	100·0
8 (3)	154·9	53·8		11·3	220·0	70·4	24·4		5.2	100·0
7 (6)	149·3			12·1	161·4	92·5			7·5	100·0
6 (7)	77·4				77·4					
5 (6)	54·0				54·0					
4-1 (35)	32·8				32·8					

NITROGEN.

No. of the bunch (figures in brackets indicate number of nuts in the bunch)	Husk Grm.	Shell Grm.	Meat Grm.	Water Grm.	Total Grm.	Husk Per cent.	Shell Per cent.	Meat Per cent	Water Per cent.	Total
16 (15)	1·25	0·45	5·13	0·025	6·855	18·2	6·6	74·8	0·4	100·0
15 (11)	1·08	0·49	4·62	0·024	6·214	17·4	7·9	74·3	0·4	100·0
14 (7)	1·67	0·39	1·49	0·014	3·564	46·8	10·9	41·7	0·4	99·8
13 (16)	0·55	0·30	1·26	0·012	2·122	25·9	14·1	59·4	0·6	100·0
12 (13)	0·90	0·34	1·26	0·021	2·521	35·7	13·5	50·0	0·8	100·0
11 (4)	1·08	0·39	1·03	0·028	2·528	42·7	15·4	40·7	1·1	99·9
10 (6)	0·95	0·34	0·65	0·056	1·996	47·6	17·0	32·6	2·8	100·0
9 (3)	0·84	0·79		0·053	1·683	49·9	46·9		3·2	100·0
8 (3)	0·87	0·45		0·052	1·372	63·4	32·8		3·8	100·0
7 (6)	1·22			0·050	1·270	96·0			4·0	100·0
6 (7)	0·66				0·66					
5 (6)	0·43				0·43					
4-1 (35)	0·29				0·29					

POTASH.

No. of the bunch (figures in brackets indicate number of nuts in the bunch)	Husk	Shell	Meat	Water	Total	Husk	Shell	Meat	Water	Total
	Grm.	Grm.	Grm.	Grm.	Grm.	Per cent.	Per cent.	Per cent.	Per cent.	
16 (15)	3·05	0·17	1·35	0·33	4·90	62·3	3·5	27·5	6·7	100·0
15 (11)	2·78	0·15	1·37	0·42	4·72	58·9	3·2	29·0	8·9	100·0
14 (7)	2·95	0·13	1·03	0·30	4·31	67·0	3·0	23·3	6·8	100·1
13 (16)	2·74	0·24	0·95	0·22	4·15	66·0	5·8	22·9	5·3	100·0
12 (13)	2·93	0·33	1·27	0·24	4·77	61·4	7·0	26·6	5·0	100·0
11 (4)	2·19	0·30	1·41	0·40	4·30	50·9	7·0	32·8	9·3	100·0
10 (6)	2·00	0·16	0·77	0·59	3·52	56·8	4·5	21·9	16·8	100·0
9 (3)	1·68	0·75		0·41	2·84	59·1	26·4		14·4	99·9
8 (3)	1·42	0·37		0·42	2·21	64·2	16·8		19·0	100·0
7 (6)	1.52			0·34	1·86	81·7			18·3	100·0
6 (7)	1·03				1·03					
5 (6)	0·80				0·80					
4-1 (35)	0·62				0·62					

PHOSPHORIC ACID.

Quantity Present in One Nut from Each Bunch.

No. of the bunch (figures in brackets indicate number of nuts in the bunch)	Husk	Shell	Meat	Water	Total	Husk	Shell	Meat	Water	Total
	Grm.	Grm.	Grm.	Grm.	Grm.	Per cent.	Per cent.	Per cent.	Per cent.	
16 (15)	0·18	0·015	0·77	0·028	0·993	18·1	1·50	77·5	2·8	100·0
15 (11)	0·24	0·018	0·72	0·032	1·010	23·7	1·8	71·3	3·2	100·0
14 (7)	0·17	0·014	0·62	0·022	0·826	20·6	1·7	75·1	2·6	100·0
13 (16)	0·19	0·024	0·55	0·017	0·781	24·3	3·1	70·4	2·2	100·0
12 (13)	0·23	0·020	0·52	0·014	0·784	29·3	2·6	66·3	1·8	100·0
11 (4)	0·21	0·032	0·43	0·033	0·705	29·9	4·5	61·0	4·7	100·0
10 (6)	0·22	0·040	0·24	0·045	0·545	40·4	7·3	44·0	8·3	100·0
9 (3)	0·21	0·16		0·053	0·423	49·4	38·0		12·5	99·9
8 (3)	0·20	0·10		0·058	0·358	56·0	28·0		16·0	100·0
7 (6)	0·253			0·061	0·314	80·6			19·4	100·0
6 (7)	0·16				0·16					
5 (6)	0·124				0·124					
4-1 (35)	0·092				0·092					

LIME (CaO).

No. of the bunch (figures in brackets indicate number of nuts in the bunch)	Husk Grm.	Shell Grm.	Meat Grm.	Water Grm.	Total Grm.	Husk Per cent.	Shell Per cent.	Meat Per cent.	Water Per cent.	Total
16 (15)	0·97	0·09	—	0·035	1·095	88·6	8·2	—	3·2	100·0
15 (11)	0·86	0·055	—	0·032	0·965	89·0	5·8	—	5·2	100·0
14 (7)	1·26	0·10	—	0·030	1·390	90·6	7·2	—	2·2	100·0
13 (16)	0·70	0·19	—	0·026	0·916	76·4	20·7	—	2·8	100·0
12 (13)	0·31	0·14	—	0·028	0·478	64·8	29·3	—	5·9	100·0
11 (4)	0·61	0·19	—	0·073	0.873	69·9	21·8	—	8·3	100·0
10 (6)	0·63	0·12	—	0·067	0·817	77·1	14·7	—	8·2	100·0
9 (3)	0·90	0·17		0·067	1·137	79·2	14·9		5·9	100·0
8 (3)	0·52	0·16		0·072	0·752	69·1	21·3		9·6	100·0
7 (6)	0·33			0·084	0·414	79·7			20·3	100·0
6 (7)	0·30				0·30					
5 (6)	0·18				0·18					
4-1 (35)	0·11				0·11					

MAGNESIA (MgO).

No. of the bunch (figures in brackets indicate number of nuts in the bunch)	Husk Grm.	Shell Grm.	Meat Grm.	Water Grm.	Total Grm.	Husk Per cent.	Shell Per cent.	Meat Per cent.	Water Per cent.	Total
16 (15)	0·58	0·016	0·26	0·025	0·881	65·9	1·8	29·5	2·8	100·0
15 (11)	0·57	0·019	0·27	0·034	0·893	63·8	2·1	30·2	3·9	100·0
14 (7)	0·63	0·018	0·19	0·022	0·860	73·3	2·1	22·1	2·5	100·0
13 (16)	0·45	0·021	0·19	0·015	0·676	66·6	3·1	28·1	2·2	100·0
12 (13)	0·32	0·010	0·27	0·023	0·623	51·4	1·6	43·3	3·7	100·0
11 (4)	0·50	0·025	0·17	0·044	0·739	67·6	·4	23·0	6·0	100·0
10 (6)	0·51	0·017	0·10	0·054	0·681	74·8	2·5	14·7	8·0	100·0
9 (3)	0·52	0·16		0·070	0·750	69·4	21·3		9·3	100·0
8 (3)	0·37	0·09		0·086	0·546	67·7	16·5		15·7	99·9
7 (6)	0·46			0·075	0·535	86·0			14·0	100·0
6 (7)	0·30				0·30					
5 (6)	0·19				0·19					
4-1 (35)	0·13				0·13					

A study of these figures throws considerable light on the food requirements of the plant, more especially in showing how far these are lost to the tree by the removal of the crop. If there is any shortage of plant food, one would expect to find it after a period of heavy cropping. In this case there are two such periods, viz., the fourteenth and the eleventh bunches. The fourteenth bunch carries only seven nuts, following two bunches which together carried twenty-six nuts, and the eleventh bunch carries only four nuts, following on two bunches which together carried twenty-nine nuts. In this latter case the strain of fruit-production proved too great for the tree, as at least two of the nuts which set, failed to develop properly. The subsequent setting of fruit after this heavy cropping was light, and only really commenced to recover in the third and first bunches, i.e., those which had newly set.

If each of the main plant foods dealt with in these analyses is taken, in the case of *nitrogen* it will be seen that the heaviest demands are made on the resources of the tree quite late on in the development of the fruit, i.e., within the last six weeks or two months. Nearly 75 per cent. of the nitrogen removed from the tree when the ripe fruit is harvested is to be found in the meat of the nut. There is, however, an appreciable quantity stored up in the husk of the fruit, though as this is not so essential for the development of the seedling as that stored up in the seed, this quantity appears to be much more variable in amount. Thus in the thirteenth and twelfth bunches the quantity in the husk is very much less than is the case in the eleventh bunch, though, judging by the quantity of dry matter, there is little difference in the development of the husk in these three bunches. The quantity stored in the meat, however, seems to be unaffected, as there is a general gradation in the quantity present in the nuts of each consecutive bunch. The gradual decrease in the quantity of nitrogen in the water is not due to this being richer, but to the fact that the cavity within the shell is much greater before the meat is formed. The maximum capacity for water appears to be at about the eighth bunch.

As regards *potash*, it will be seen that the demand or this commences early on in the development of the fruit. The greater part of the potash is stored up in the husk, though the quantity in the meat is also considerable. The reason for this is that the young seedling which comes from the nut after this is grown, requires only a limited supply of potash till after the leaves have emerged and spread. As soon as this occurs the quantity of potash required by the leaves is great. Its presence in the leaf is essential for the assimilation of carbon dioxide for the manufacture of carbohydrates. By the time that the leaves have spread, the root-system of the seedling will have ramified through the husk, from which it can extract the potash which is required. The quantity of potash in the meat seems to be greatest at the time when the meat is being laid down, after which it seems to be reduced when no longer required for this work. The quantity in the husk, however, when once laid down, seems to be retained, as there is a much more even gradation in the amount stored here than in the meat. The supply of potash seems to be readily forthcoming when it is required. It is probable that, this being a much more soluble salt than most other plant foods, there is much more elasticity in the supply, it being taken away from other parts of the plant, resulting possibly in the retardation of growth for the time being, and brought to where its presence is essential.

Phosphoric Acid.—This, like nitrogen, is mainly stored up in the meat of the nut, but instead of there being a sudden increase as the seed ripens, as in the case of nitrogen, the store is built up gradually. Phosphates are essential, along with nitrogen, for the formation of the protoplasm of the living cells of the young plant, when this commences to grow, and hence the necessity for this to be stored up within the seed itself. That stored up in the husk is placed there at a very early stage in the development of the fruit, since the amount is practically constant from the time that the fruit coat reaches its maximum size. It appears, however, that this store can be drawn upon when necessity arises. In the case of the fourteenth bunch, the quantity in the husk and the shell is much less than in the preceding and succeeding bunches though that in the meat shows the regular gradation of an essential minimum supply. It is quite possible that phosphates rather than potash are the limiting factor of production in this particular case. The quantity stored up is low when compared with nitrogen and potash, and it is probable that phosphatic manuring would greatly increase this proportion. In the case of rice, grown on soils deficient in phosphates, it has been proved that the addition of even small dressings of phosphatic manures has the effect of greatly increasing the quantity of phosphate in the grain, whereas this effect is not seen in the case of potash and nitrogen when manures containing these plant foods are applied.

Lime.—The analysis of the soil in which this tree was grown is given on p. 138. Here it will be seen that the quantity of lime both in the soil and the subsoil is merely a trace, and one expects therefore that the quantity present in the fruit will be the minimum necessary. This is not required by the germ when this starts to grow. Other alkali salts are said to be capable of taking its place. Hence the meat of the nut merely shows a trace, though there is a small quantity in the water of the ripe nut. The majority of the lime present in the fruit is found in the husk, and since the supply is scanty, the quantity present seems to fluctuate with what is available. Thus in the fourteenth bunch where there are only seven nuts the quantity present in the husk is much greater than in the preceding two bunches where the number of nuts is greater, In the twelfth bunch, where there are thirteen nuts following a bunch where there are sixteen nuts, the quantity is extremely low.

Magnesia.—There is a small quantity of this element stored up in the meat. This is essential here, since magnesia is necessary for the formation of chlorophyll—the green colouring matter of the leaf and of other green parts of the plant and without which the plant is incapable of manufacturing carbo-hydrates from the air. Except for this function magnesia is not, as far as is known, of any considerable importance to the plant, and very few soils show a deficiency in this. In fact the trouble in many tropical countries where soils are of igneous origin is that this is present in too great a quantity.

This study of the analysis of the fruit of a single tree not only shows the amount of plant food lost to the tree by the ripening of the fruit, but it shows what the plant requires for the development of fruit to come. Taking the average number of fruit on a bunch as eight and the number of bunches in different stages of development on the tree at any one time as sixteen, we arrive at the following figures which show the demand which the tree is making on its resources on account of fruit development.

The demand at any one time is as follows :—

Nitrogen 252 grammes or 0·554 lbs.

Potash (K_2O) 320 grammes or 0·7 lbs.

Phosphoric acid (P_2O_5) 57 grammes or 0·125 lbs.

Calcium (CaO) 76 grammes or 0·167 lbs.

Magnesia (MgO) 62 grammes or 0·136 lbs.

The following figures show the loss per bunch of eight fruit and the loss per tree per annum taking the crop as sixteen bunches of eight fruits each :—

	Loss per Bunch		Loss per Annum			
	Husk and Shell	Meat and Water	Husk and Shell		Meat and Water	
	gms.	gms.	gms.	lbs.	gms.	lbs.
Nitrogen	13·60	41·24	217·6	0·48	659·8	1·45
Potash (K_2O) ...	25·76	13·44	412·16	0·9	215·0	0·47
Phosphoric acid (P_2O_5)	1·56	6·38	24·96	0·055	102·14	0·225
Lime (CaO) ...	8·48	0·28	135·62	0·19	4·48	0·01
Magnesia (MgO)...	4·77	2·28	76·29	0·17	36·48	0·08

These figures represent a tree bearing 128 nuts a year. This is not an unusual yield for nuts on the Malabar coast, nor for nuts grown in any coconut country. An average of sixty nuts per tree is nothing out of the usual, while an average of ninety nuts per tree is not uncommon. Taking good and bad trees, a large number will produce as many as 128 nuts.

Comparing the figures given in these analyses with those given by Copeland, we find a considerable difference. Taking the total quantity of nitrogen, potash and phosphoric acid as 100, the following are the percentages of each of these in the analyses given here. Nitrogen, 53·8 per cent.; potash, 38·4 per cent.; and phosphoric acid, 7·8 per cent. Copeland's figures give nitrogen, 43·5 per cent.; potash, 44·3 per cent. and phosphoric acid, 12·2 per cent. Such a difference is quite understandable when it is considered that Copeland's analysis is from a nut grown on the rich San Ramon coconut belt and the analyses given here are from nuts grown on a poor sandy loam. The former shows more what the coconut fruit will take in when it has the chance, and the latter what the coconut can manage with when not so favourably situated.

The divisions made in the table given above have been made in order to show what is lost to the estate by the manufacture of copra, and as far as the mineral elements contained in the fruit, what remains, and can be utilized on the estate. Thus, in the case of potash, nearly two-thirds of that taken by the fruit is in the husk and shell, while in the case of phosphates only one-quarter of that in the fruit is in the husk and shell. Practically all the lime is in the husk and shell and two-thirds of the magnesia.

The following figures are of interest in showing how the plant can economize in plant food.

In comparing Walker's analyses of "dead-ripe" nuts quoted by Copeland with those given here, we get the following :—

		Walker gms.		Norris gms.
Husk	...	520	...	329
Shell	...	201	...	145
Meat	...	453	...	298
Water	...	384	...	101

If the water within the nut is disregarded, we get the following percentages :—

		Walker per cent.		Norris per cent.
Husk	...	44·3	...	42·6
Shell	...	17·1	...	18·8
Meat	...	38·6	...	38·6

Taking the percentage distribution of the main elements of plant food in the different parts of the fruit, we get very different results. In the meat or endosperm, this difference is small, but in the husk and shell the differences are very marked and indicate that when the plant is pressed for food for the endosperm it does not leave any surplus where it will not be required by the young plant after germination.

		San Ramon nut (Copeland)			Malabar nut (Norris)		
		N per cent.	K_2O per cent.	P_2O_5 per cent.	N per cent.	K_2O per cent.	P_2O_5 per cent.
Husk	...	23·2	53·4	0·8	18·3	66·7	18·6
Shell	...	9·5	12·9	20·7	6·6	3·7	1·5
Meat	...	67·3	33·7	78·5	75·1	29·6	79·9
Total	...	100·0	100·0	100·0	100·0	100·0	100·0

In order to see how the regular bearing of nuts affects the distribution of plant food within the plant, the following table is of interest comparing the analysis of the parts of a "barren" tree—i.e., one which only bears male flowers and consequently never ripens any nuts—with that of a regular bearing tree.

	"Barren" tree per cent.	Bearing tree per cent.
Percentage of Ash to Dry Material:		
Stipules	2·81	1·06
Inflorescence, spathe of ripe bunch	3·17	2·68
Roots	3·33	3·63
Inflorescence, spathe about to open	4·28	3·36
Stem	4·30	5·45
Leaflets	5·25	4·67
Inflorescence, spadix of ripe bunch	6·40	6·09
Leaf stalk and peteole	7·04	5·90
Inflorescence, spadix about to open	13·55	5·41
Percentage of Magnesia (MgO) in Ash:		
Leaf stalk and peteole	6·30	8·41
Inflorescence, spathe about to open	10·88	10·56
,, spadix of ripe bunch	12·94	10·35
Stem	13·58	12·10
Inflorescence, spadix about to open	14·20	7·85
Leaflets	15·05	13·32
Inflorescence, spathe of ripe bunch	18·12	13·06
Roots	25·18	19·10
Stipules	28·93	6·70
Percentage of Lime (CaO) in Ash:		
Inflorescence, spadix of ripe fruit	4·20	1·81
,, spathe about to open	6·22	
Leaf stalk and peteole	6·45	5·16
Leaflets	7·01	6·55
Stem	7·05	5·11
Roots	7·06	5·49
Inflorescence, spadix about to open	7·22	
,, spathe of ripe bunch	10·45	12·31
Stipules	16·28	8·66

Percentage of Phosphoric Acid (P_2O_5) in Ash:	"Barren" Tree per cent.	Bearing Tree per cent.
Stipules	0·94	2·99
Stem	1·84	1·03
Roots	1·92	1·21
Inflorescence, spathe of ripe bunch ...	3·35	3·17
Leaf stalk and peteole	4·09	3·30
Inflorescence, spadix of ripe bunch ...	4·20	1·64
,, spathe about to open ...	5·18	3·16
Leaflets	6·80	5·84
Inflorescence, spadix about to open ...	8·57	7·23

Percentage of Potash (K_2O) in Ash:		
Leaf stalk and peteole	3·77	4·97
Stem	5·36	3·91
Stipules	7·77	3·50
Leaflets	9·67	13·08
Inflorescence, spathe about to open ...	15·80	20·46
Roots	16·27	8·27
Inflorescence, spathe of ripe bunch ...	17·07	3·73
,, spadix about to open ...	21·34	27·90
,, spadix of ripe bunch ...	21·36	14·45

So far we have mainly considered what the harvested crop removes from the tree. There is, however, the important question of what is required by the plant in order to keep it in a healthy growing condition, which will enable it to resist disease and at the same time to continue to produce crops of nuts. To appreciate this, a careful study of the analyses graphically shown on Plates XXX to XXXV is necessary. These analyses are given in detail in the following tables, and tables are also given to show the green weight of the different parts of the tree at different stages of growth and how far this green weight is represented by dry weight.

PLATE XXX.—PERCENTAGE OF "DRY MATTER" TO TOTAL WEIGHT OF THE GREEN PLANT.

COCONUT SEEDLING ONE YEAR OLD.

	Per cent.
"Apple"	9·33
Leaflets...	18·38
Leaf stalk and peteole	18·50
Roots ...	27·43
Husk of seed nut	36·75
Meat of seed nut	73·81
Shell of seed nut...	81·43

COCONUT SEEDLING TWO YEARS OLD.

"Apple"	9·43
Leaf stalk and peteole	17·76
Leaflets...	23·93
Husk of seed nut	26·53
Roots ...	32·74
Shell of seed nut...	74·50

YOUNG TREE ABOUT SIX YEARS OLD (NOT YET BEARING).

Cabbage	4·51
Stem ...	9·11
Leaf stalk and peteole (tender)	17·83
,, ,, (green)	17·92
,, ,, (old)	23·43
Leaflets (tender)...	27·42
,, (green) ...	30·46
,, (old) ...	34·19
Stipules	45·10
Roots ...	47·06

BEARING TREE.

Inflorescence (4) fruit	9·93
,, (1) spadix	13·90
,, (2) fruit	19·14
,, (1) ovule	20·40
Leaf stalk and peteole	20·71
Inflorescence (5) spadix	25·98
,, (4) ,,	29·16
Leaflets...	29·56
Inflorescence (5) fruit	43·42
Roots ...	43·62
Stem ...	49·30
Inflorescence (1) spathe	64·33
,, (2) ,,	63·16
Stipules...	84·92

Note.—Inflorescence (1) spathe just opened; (2) after fertilization; (3) after fruit has set; (4) full grown, before the formation of the endosperm; (5) ripe fruit.

Plate XXX.

PERCENTAGE OF "DRY MATTER" TO TOTAL WEIGHT OF THE GREEN PLANT.

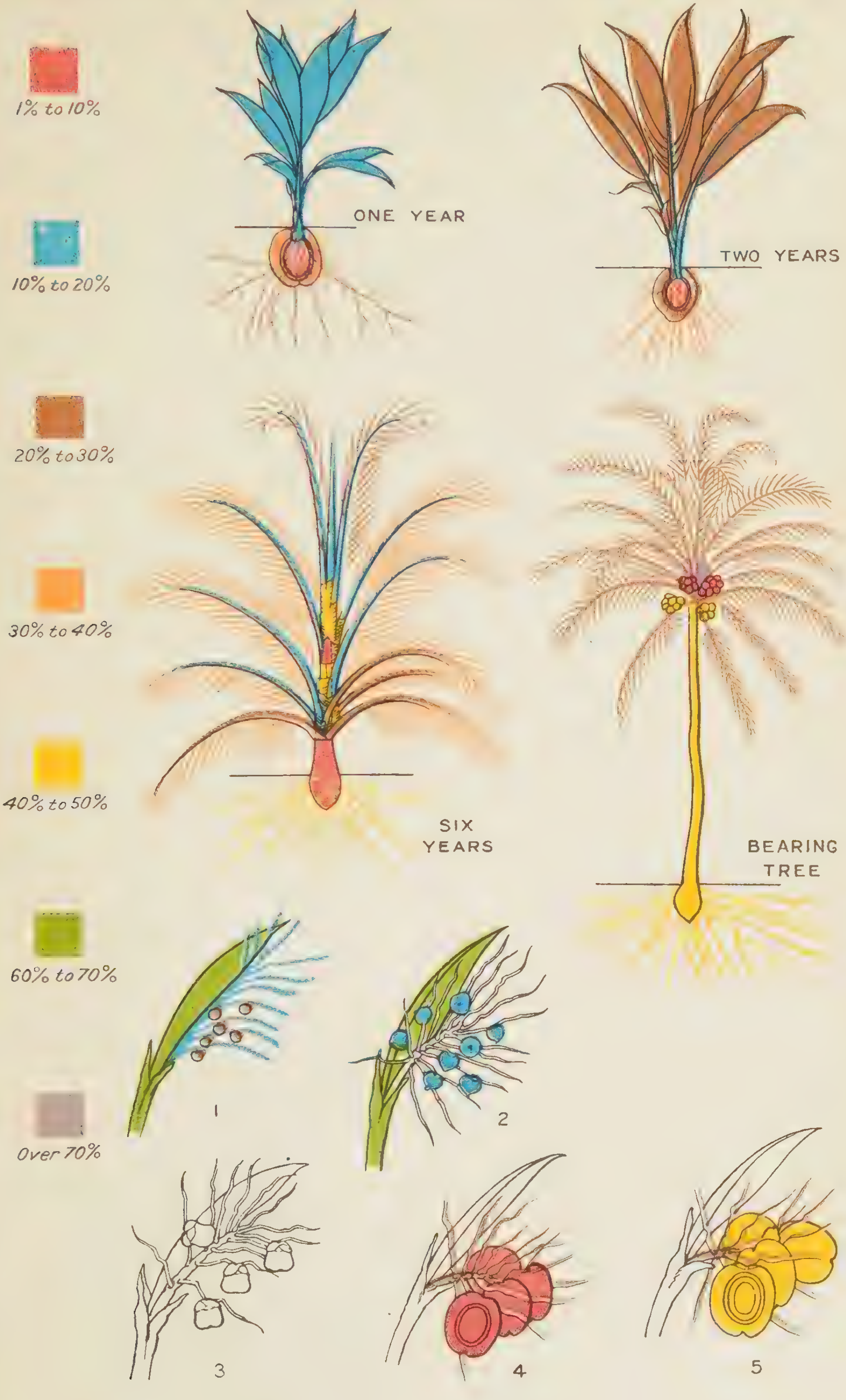


Plate XXXI.

PERCENTAGE OF ASH IN DRY MATERIAL.

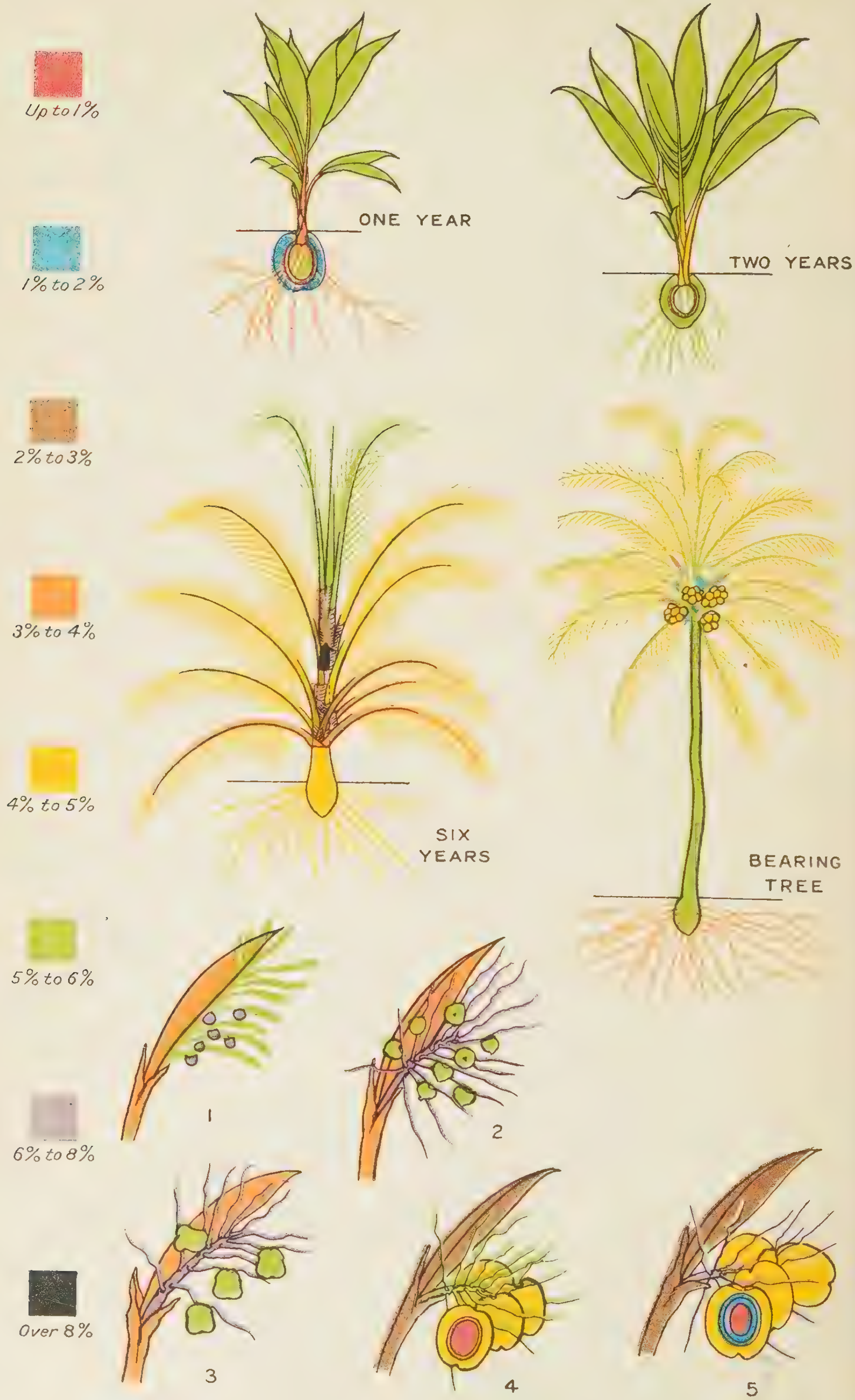


PLATE XXXI.—PERCENTAGE OF ASH TO DRY MATERIAL.

COCONUT SEEDLING ONE YEAR OLD.

	Per cent.
Shell	0·37
Husk	1·69
Roots	3·10
Leafstalk and peteole	3·71
"Apple"	5·24
Leaflets	5·94

COCONUT SEEDLING TWO YEARS OLD.

Shell	0·64
Leafstalk and peteole	4·06
Roots	5·25
Husk	5·63
Leaflets	5·85

YOUNG TREE ABOUT SIX YEARS OLD (NOT YET BEARING).

Stipule	2·04
Leafstalk and peteole (old)	3·23
Leaflets (green)	4·04
,, (old)	4·51
Leafstalk and peteole (green)	4·51
Roots	4·69
Stem	5·00
Leaflets (tender)	5·31
Leafstalk and peteole (tender)	5·99
"Cabbage"	10·79

BEARING TREE.

Inflorescence (4) milk	1·00
,, (5) ,,	1·00
Stipules	1·06
Inflorescence (5) shell	1·11
,, (4) spathe	2·09
,, (5) ,,	2·68
,, (1) ,,	3·36
,, (3) ,,	3·50
,, (2) ,,	3·63
Roots	3·63
Inflorescence (5) husk	4·38
Leaflets	4·67
Inflorescence (4) fruit	4·98
,, (3) ,,	5·07
,, (4) spadix	5·08
,, (1) ,,	5·41
Stem	5·45
Inflorescence (2) fruit	5·67
Leafstalk and peteole	5·90
Inflorescence (5) spadix	6·09
,, (3) ,,	6·67
,, (2) ,,	6·85
,, (1) ovule	7·05

Note.—Inflorescence (1) Spathe just opened; (2) after fertilization; (3) after fruit has set; (4) full grown, before the formation of the endosperm; (5) ripe fruit.

PLATE XXXII.—PERCENTAGE OF POTASH (K_2O) IN ASH.

COCONUT SEEDLING ONE YEAR OLD.

	Per cent.
Husk	1.5
Shell	9·97
Roots	19·45
Leafstalk and peteole	26·82
"Apple"	34·59
Leaflets	41·50

COCONUT SEEDLING TWO YEARS OLD.

Husk	0·59
"Apple"	1·30
Shell	2·01
Roots	5·86
Leafstalk and peteole	15·89
Leaflets	20·37

YOUNG TREE ABOUT SIX YEARS OLD (NOT YET BEARING).

Stipules	2·68
Roots	3·33
Leafstalk and peteole (old)	3·92
,, ,, ,, (green)	4·24
Stem	10·89
Leaflets (old)	13·75
,, (green)	18·13
"Cabbage"	31·16
Leafstalk and peteole (tender)	34·60
Leaflets (tender)	40·94

BEARING TREE.

Stipules	3·50
Inflorescence (5) spathe	3·73
Stem	3·91
Leafstalk and peteole	4·97
Roots	8·27
Inflorescence (4) spathe	11·48
,, (4) spadix	12·21
Leaflets	13·08
Inflorescence (5) spadix	14·45
,, (3) ,,	19·79
,, (1) spathe	20·46
,, (2) ,,	20·66
,, (3) ,,	22·86
,, (2) spadix	23·65
,, (5) husk	24·66
,, (4) fruit	25·90
,, (1) spadix	27·90
,, (5) kernel	29·80
,, (5) milk	31·10
,, (5) shell	31·60
,, (2) fruit	38·97
,, (1) ovule	39·22
,, (3) fruit	47·69
,, (4) milk	50·49

Note.—Inflorescence (1) spathe just opened; (2) after fertilization; (3) after fruit has set; (4) full grown before the formation of the endosperm; (5) ripe fruit.

Plate XXXII.

PERCENTAGE OF POTASH (K_2O) IN ASH.

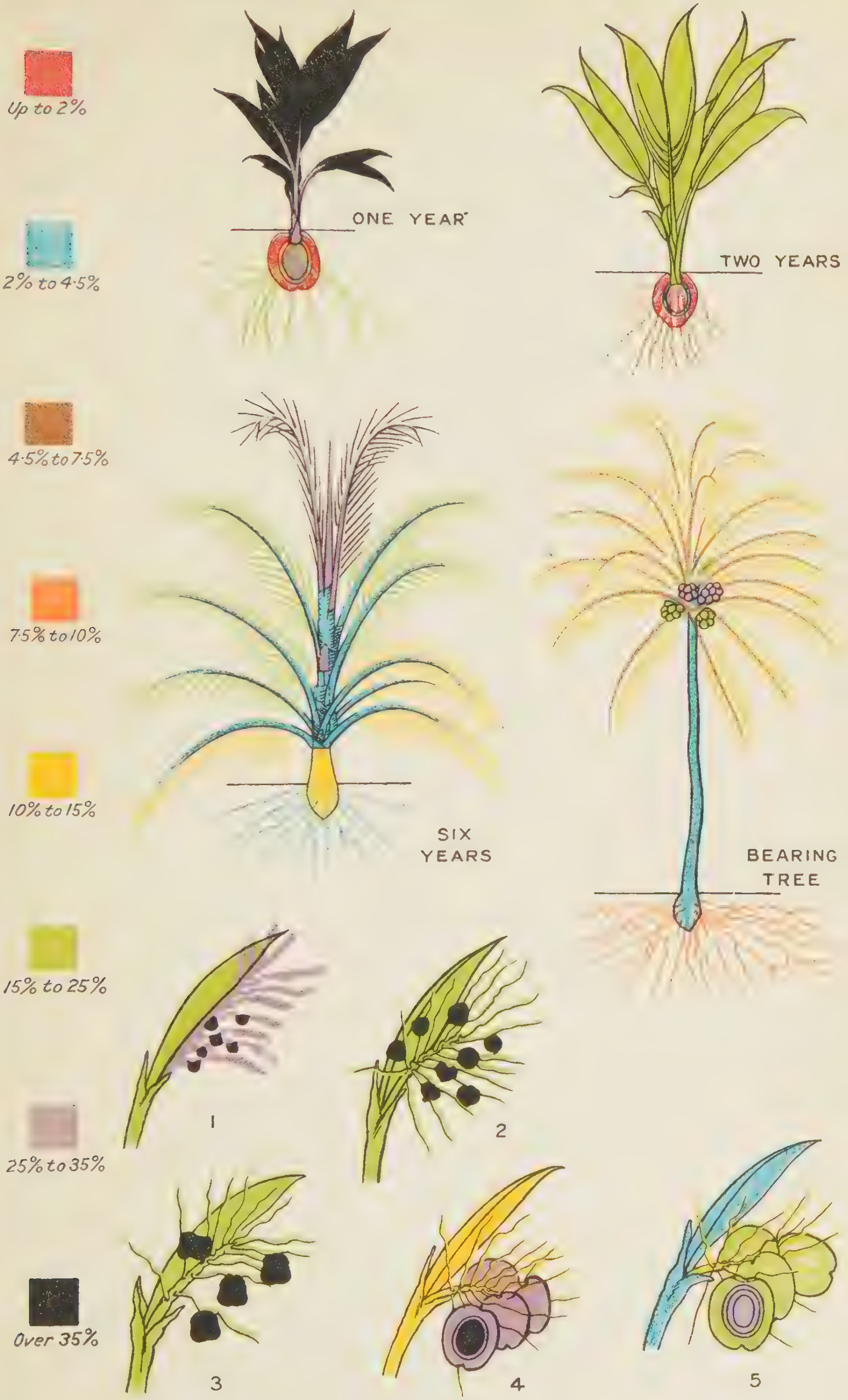


Plate XXXIII.

PERCENTAGE OF PHOSPHORIC ACID (P_2O_5) IN ASH.

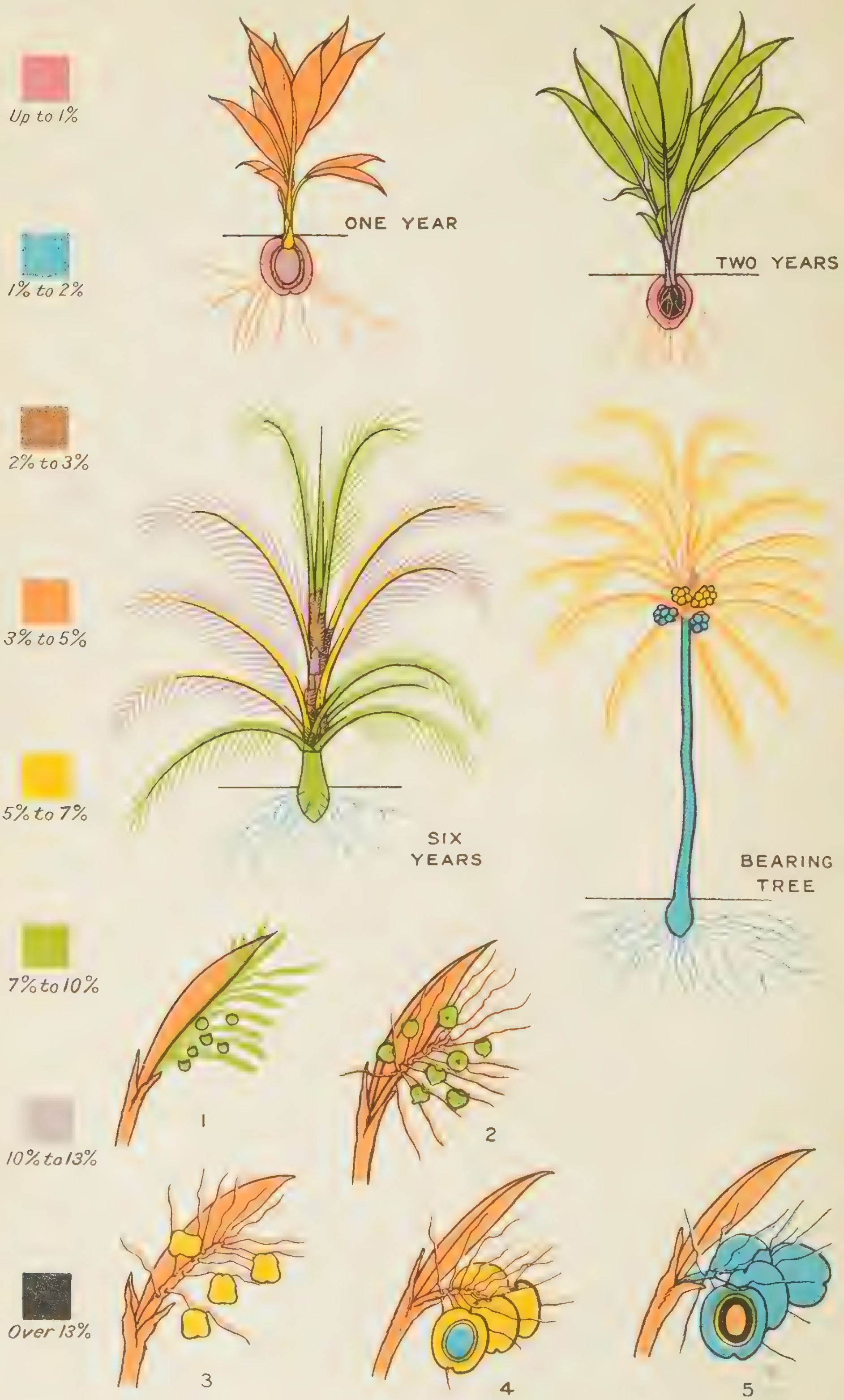


PLATE XXXIII.—PERCENTAGE OF PHOSPHORIC ACID (P_2O_5) IN ASH.

COCONUT SEEDLING ONE YEAR OLD.

	Per cent.
Husk	0·62
Shell	2·71
Roots	3·04
Leaflets...	4·94
Leafstalk and peteole	5·54
"Apple"	12·92

COCONUT SEEDLING TWO YEARS OLD.

Husk	0·59
Roots	3·78
Leaflets...	7·40
Leafstalk and peteole	10·19
Shell	12·01
"Apple"	14·60

YOUNG TREE ABOUT SIX YEARS OLD (NOT YET BEARING).

Roots	1·19
Stipules...	2·42
Leafstalk and peteole (green)	5·19
„ „ (tender)	7·39
„ „ (old)	8·02
Stem	8·50
Leaflets (old)	8·50
„ (tender)	9·60
Cabbage	11·22
Leaflets (green)	11·97

BEARING TREE.

Stem	1·03
Roots	1·21
Inflorescence (5) husk	1·60
„ (5) spadix	1·64
„ (4) milk	1·83
Stipules...	2·99
Inflorescence (1) spathe	3·16
„ (5) „	3·17
„ (2) spadix	3·21
Leafstalk and peteole	3·30
Inflorescence (4) spadix	3·35
„ (3) spathe	3·43
„ (3) spadix	3·45
„ (2) spathe	3·58
„ (5) milk	3·70
„ (4) spathe	4·11
„ (5) shell	5·32
„ (4) fruit	5·62
Leaflets...	5·84
Inflorescence (3) fruit	6·90
„ (1) spadix	7·23
„ (1) ovule	7·29
„ (2) fruit	8·21
„ (5) kernel	25·17

Note.—Inflorescence (1) spathe just opened; (2) after fertilization; (3) after fruit has set; (4) full grown, before the formation of the endosperm; (5) ripe fruit.

PLATE XXXIV.—PERCENTAGE OF LIME (CaO) N ASH.

COCONUT SEEDLING ONE YEAR OLD.

	Per cent.
Roots	2·15
"Apple"	2·78
Husk	2·99
Leaflets	4·75
Leafstalk and peteole	5·24
Shell	7·06

COCONUT SEEDLING TWO YEARS OLD.

Roots	2·46
Husk	3·82
Leaflets	8·90
Leafstalk and peteole	12·60
Shell	12·68
"Apple"	21·85

YOUNG TREE ABOUT SIX YEARS OLD (NOT YET BEARING).

Roots	1·31
Leafstalk and peteole (tender)	1·08
Leaflets (tender)	1·62
,, (green)	6·66
Stem	6·75
Leaflets (old)	7·08
"Cabbage"	8·95
Stipules	8·42
Leafstalk and peteole (old)	11·37
,, ,, (green)	12·26

BEARING TREE.

Inflorescence (5) kernel	9.04
,, (5) spadix	1·81
,, (3) fruit	2·17
,, (5) husk	2·24
,, (5) shell	2·97
,, (2) spadix	3·21
,, (4) fruit	3·41
,, (1) spadix	3·51
,, (4) milk	4·35
,, (3) spathe	4·86
,, (1) spathe	4·95
,, (2) fruit	5·11
Stem	5·11
Leafstalk and peteole	5·16
Roots	5·49
Inflorescence (5) milk	5·55
,, (1) ovule	5·89
,, (2) spathe	6·34
Leaflets	6·55
Inflorescence (4) spadix	7·28
Stipules	8·66
Inflorescence (3) spadix	8·99
,, (5) spathe	12·31
,, (4) ,,	18·18

Note.—Inflorescence (1) spathe just opened; (2) after fertilization; (3) after fruit has set; (4) full grown before the formation of the endosperm; (5) ripe fruit.

Plate XXXIV.

PERCENTAGE OF LIME (CaO) IN ASH.

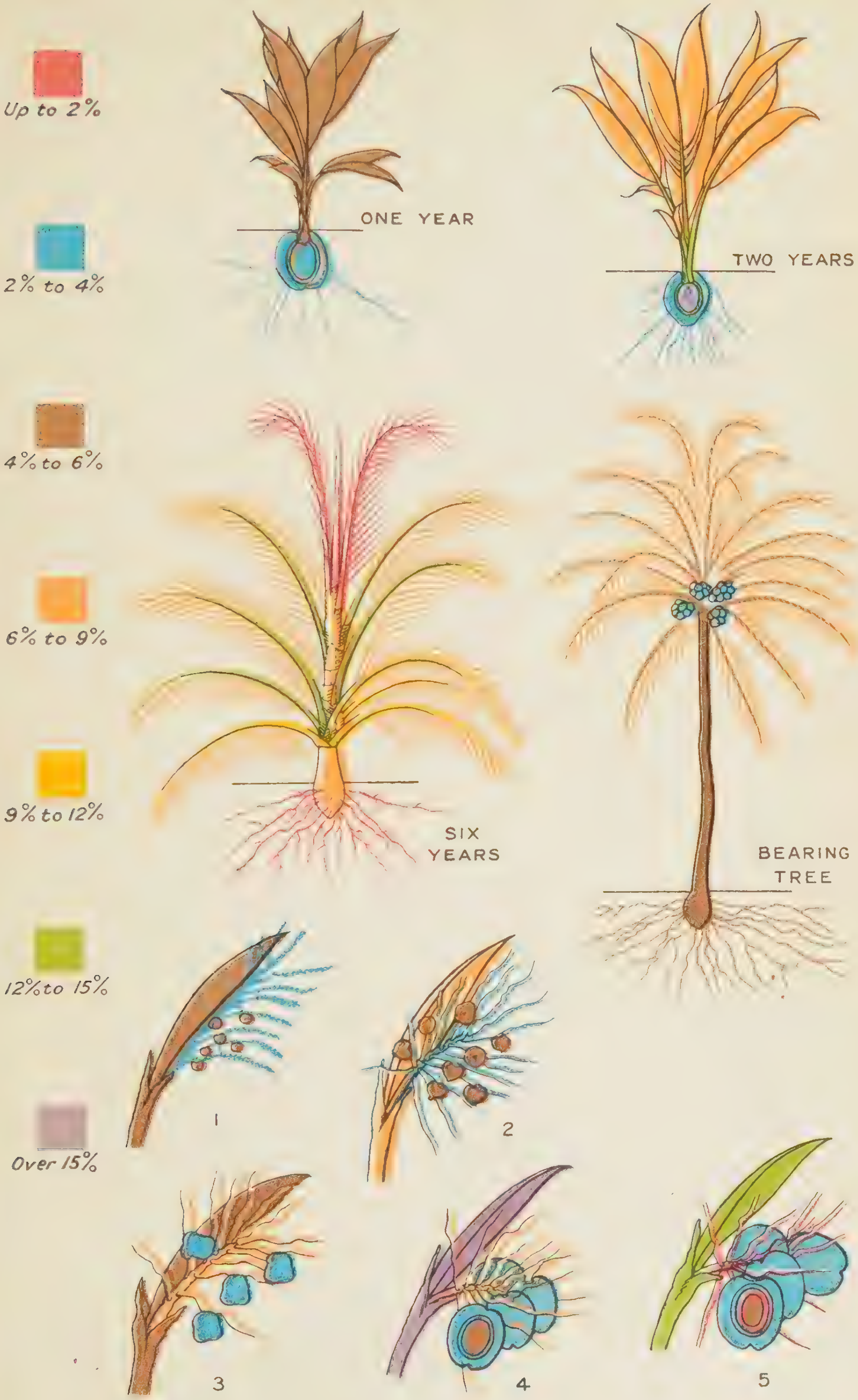


Plate XXXV.

PERCENTAGE OF MAGNESIA (MgO) IN ASH.

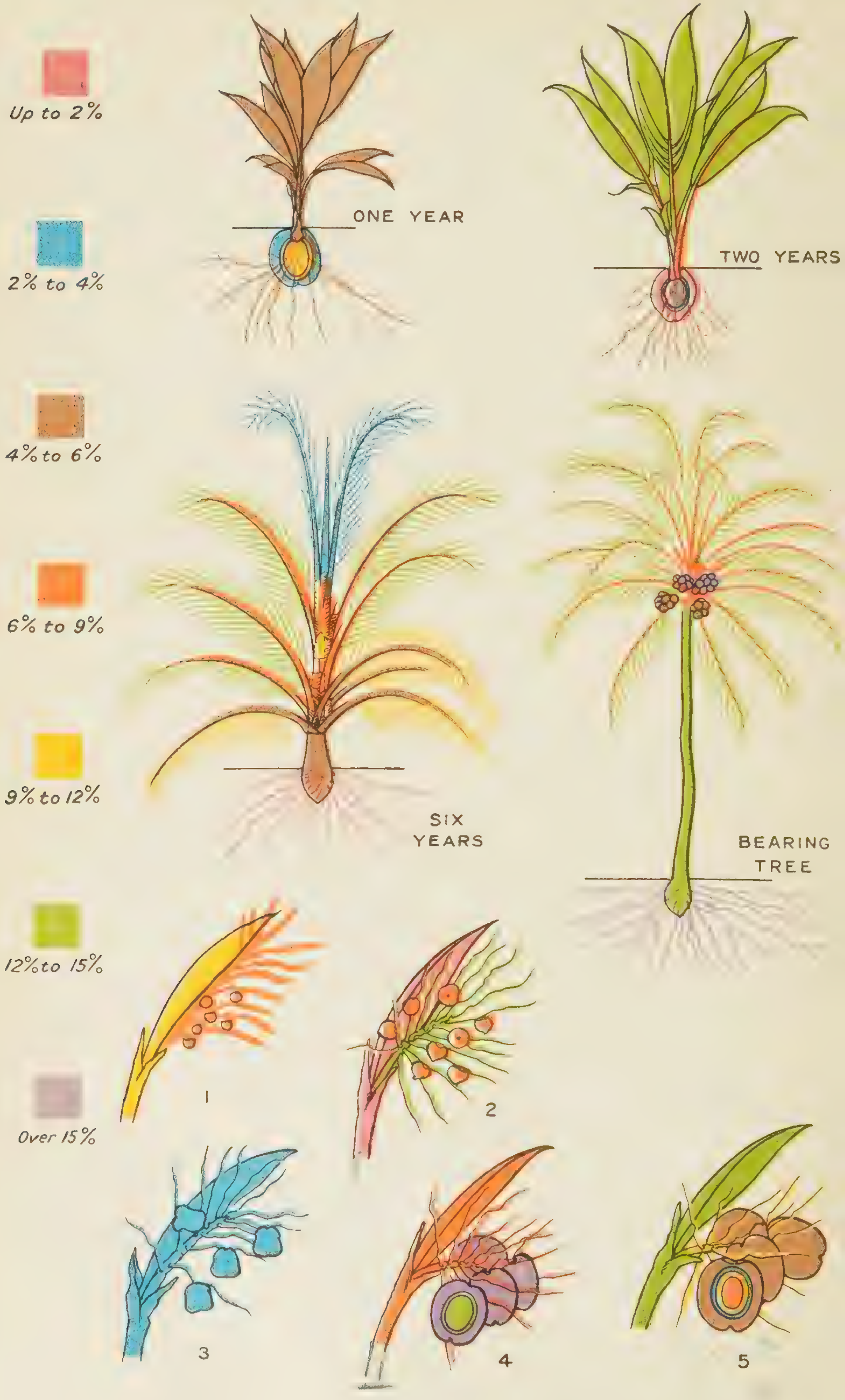


PLATE XXXV.—PERCENTAGE OF MAGNESIA (MgO) ASH

COCONUT SEEDLING ONE YEAR OLD.

	Per cent.
Husk	3·25
Leafstalk and peteole	4·96
Roots	5·21
Leaflets	5·49
Shell	7·94
"Apple"	9·15

COCONUT SEEDLING TWO YEARS OLD.

Husk	1·76
Shell	3·55
Roots	4·50
Leafstalk and peteole	8·85
Leaflets	12·78
"Apple"	29·12

YOUNG TREE ABOUT SIX YEARS OLD (NOT YET BEARING).

Roots	1·83
Leaflets (tender)	3·46
Leafstalk and peteole (tender)	3·78
Stem	5·66
Leafstalk and peteole (old)	5·67
Stipules	6·84
Leafstalk and peteole (green)	6·84
"Cabbage"	9·02
Leaflets (old)	11·75
„ (green)	12·80

BEARING TREE.

Inflorescence (2) spathe	0·91
„ (3) „	3·71
„ (5) shell	3·87
„ (3) spadix	3·90
„ (3) fruit	3·95
„ (5) husk	4·79
„ (2) fruit	6·23
„ (5) water	6·55
Stipules	6·70
Inflorescence (4) spadix	7·48
„ (1) „	7·85
„ (1) ovule	8·22
Leafstalk and peteole	8·41
Inflorescence (4) spathe	8·61
„ (5) spadix	10·35
„ (1) spathe	10·56
„ (5) kernel	11·92
Stem	12·10
Inflorescence (4) water	12·15
„ (2) spadix	12·41
„ (5) spathe	13·06
Leaflets	13·32
Inflorescence (4) fruit	15·46
Roots	19·10

Note.—Inflorescence (1) Spathe just opened; (2) after fertilization; (3) after fruit has set; (4) full grown, before the formation of the endosperm; (5) ripe fruit.

ANALYSES OF THE DIFFERENT PARTS OF A COCONUT TREE AGED BETWEEN ONE AND TWO YEARS FROM GERMINATION.

	Root	Peteole and Leafstalk	Leaflets	Husk of seed nut	Shell of seed nut	"Apple"
Moisture ...	7·77	8·91	7·95	9·19	8·70	4·00
Loss on ignition	89·35	87·66	86·58	89·27	90·96	90·97
Insoluble mineral matter	1·15	0·24	0·65	1·23	0·13	0·057
Soluble mineral matter	1·73	3·19	4·82	0·31	0·21	4·973
Total	100·0	100·0	100·0	100·0	100·0	100·0
Lime	0·062	0·18	0·26	0·046	0·024	0·14
Magnesia ...	0·15	0·17	0·30	0·050	0·027	0·46
Phosphoric acid (P_2O_5)	0·088	0·19	0·27	0·0096	0·0092	0·65
Potash (K_2O)	0·56	0·92	2·27	0·024	0·034	1·74

MOISTURE CONTENT OF A COCONUT TREE BETWEEN ONE AND TWO YEARS FROM GERMINATION.

	Green weight gms.	Total amount of water		Dry matter	
		Per cent.	gms.	Per cent.	gms.
"Apple"	175	90·67	158·58	9·33	16·42
Leaflets	66	73·62	48·59	18·38	17·41
Leafstalk and peteole ...	114	81·50	92·93	18·50	21·07
Roots	64	72·57	46·44	27·43	17·56
Husk of seed nut ...	407	63·25	257·44	36·75	149·56
Meat of seed nut ...	134	26·19	35·09	73·81	98·91
Shell of seed nut ...	177	18·57	32·87	81·43	144·13

Analyses of the Different Parts of a Coconut Tree aged Between Two and Three Years from Germination.

	Roots	Peteole and leafstalk	Leaflets	Husk of seed nut	Shell of seed nut	"Apple"
Moisture ...	8·06	8·22	7·72	10·09	7·69	92.94
Loss on ignition	87·11	88·05	86·88	84·79	91·72	
Insoluble mineral matter	2·23	0·28	1·44	3·86	0·30	0·07
Soluble mineral matter ...	2·60	3·45	3·96	1·26	0·29	6·99
Total	100·0	100·0	100·0	100·0	100·0	100·0
Lime	0·13	0·47	0·48	0·20	0·075	1·54
Magnesia ...	0·22	0·33	0·69	0·09	0·021	2·06
Phosphoric acid (P_2O_5)	0·20	0·38	0·40	0·03	0·071	1·03
Potash (K_2O)	0·31	0·59	1·10	0·03	0·012	0·092

Moisture Content of a Coconut Tree aged between Two and Three Years from Germination.

	Green weight grms.	Total amount of water		Dry matter	
		Per cent.	grm.	Per cent.	grm.
"Apple"	33	90·57	29·88	9·43	3·12
Leaf-stalk and peteole...	743	82·24	611·16	17·76	131·84
Leaflets	510	76·07	388·03	23·93	121·97
Husk of seed nut ...	482	73·47	354·09	26·53	127·91
Roots	230	67·26	154·72	32·74	75·28
Shell of seed nut ...	118	25·50	30·09	74·50	87·91

ANALYSES OF THE DIFFERENT PARTS OF A COCONUT TREE ABOUT SIX TO SEVEN YEARS OLD. (NOT YET BEARING.)

	Root	Stem	Cabbage	Stipules	Peteoles and leaf-stalks			Leaflets		
					Old	Green	Tender	ld	Green	Tender
Moisture	8·67	8·18	7·48	6·85	7·49	7·18	7·33	7·08	7·21	7·61
Loss on ignition ...	87·12	87·23	82·54	91·25	89·52	88·58	87·42	88·91	89·04	87·48
Insoluble mineral matter	2·69	1·08	0·82	0·98	0·30	0·27	0·11	1·44	0·86	0·45
Soluble mineral matter	1·52	3·51	9·16	0·92	2·69	3·97	5·14	2·57	2·89	4·46
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Lime	0·055	0·31	0·84	0·17	0·34	0·52	0·06	0·29	0·25	0·08
Magnesia	0·079	0·26	0·90	0·13	0·17	0·29	0·21	0·47	0·48	0·17
Phosphoric acid (P_2O_5)	0·082	0·39	1·12	0·046	0·24	0·22	0·41	0·34	0·45	0·45
Potash (K_2O)	0·14	0·50	3·11	0·051	0·12	0·18	1·92	0·55	0·68	2·01

MOISTURE CONTENT OF A COCONUT TREE ABOUT SIX TO SEVEN YEARS OLD (NOT YET BEARING).

	Green weight Grm.	Total amount of water		Dry matter	
		Per cent.	Grm.	Per cent.	Grm.
"Cabbage"	1637	95·49	1536·36	4·51	73·64
Stem	13608	90·89	12367·00	9·11	1241·00
Leaf-stalk and peteole (tender) 3 leaves	8969	82·17	7370·00	17·83	1599·00
Leaf-stalk and peteole average	4320	82·13	3548·00	17·87	772·00
5th to 9th leaf (green)—					
5th leaf	3930	80·20	3152·00	19·80	778·00
6th leaf	4749	84·42	3909·00	15·58	840·00
7th leaf	4202	80·98	3403·00	19·02	799·00
8th leaf	3913	84·72	3315·00	15·28	598·00
9th leaf	4808	82·38	3961·00	17·62	847·00
Leaf-stalk and peteole (old) 4 leaves	7614	77·33	5888·00	22·67	1726·00
Leaflets (tender) 3 leaves	3713	72·58	2685·00	27·42	1028·00
Leaflets (green) average	1461	69·54	1016·00	30·46	445·00
5th to 9th leaf—					
5th leaf	1352	69·7	942·00	30·3	410·00
6th leaf	1538	71·1	1093·00	28·9	445·00
7th leaf	1722	71·9	1238·00	28·1	484·00
8th leaf	1540	70·0	1078·00	30·0	462·00
9th leaf	1152	63·2	728·00	36·8	424·00
Leaflets (old) 4 leaves	3688	65·81	2427·00	34·19	1261·00
Stipules (average of 10)	125	54·74	68·3	45·26	56·7
Roots (average of 3 samples)	34	52·94	18·00	47·06	16·00
Roots (young) ...	36	66·8	24·05	33·2	11·95
Roots (medium) ...	33	49·67	16·39	50·33	16·61
Roots (old)	33	41·09	13·56	58·91	19·44

ANALYSES OF THE DIFFERENT PARTS OF A BEARING COCONUT TREE.

	Root	Stem	Stipules	Peteole and leaf-stalk	Leaflets	(1) Inflorescence about to open			(2) Inflorescence after fertilization		
						Spathe	Spadix	Ovule	Spathe	Spadix	Fruit
Moisture	1·98	1·41	8·82	11·29	8·45	9·71	10·58	8·53	5·14	8·58	10·80
Loss on ignition ...	94·45	93·21	90·21	83·48	87·27	87·26	84·58	85·02	91·42	85.16	84·14
Insoluble mineral matter	1·37	3·93	0·51	0·19	1·53	0·39	0·39	0·35	0·71	0·67	0·26
Soluble mineral matter	2·20	1·45	0·46	5·04	2·75	2·64	4·45	6·10	2·73	5·59	4·80
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·00	100·00	100·00
Lime	0·20	0·27	0·084	0·27	0·28	0·15	0·17	0·38	0·22	0·20	0·26
Magnesia	0·68	0·65	0·065	0·44	0·57	0·32	0·38	0·53	0·031	0·78	2·34
Phosphoric acid (P_2O_5)	0·043	0·055	0·029	0·17	0·25	0·096	0·35	0·47	0·12	0·20	0·41
Potash (K_2O)	0·29	0·21	0·034	0·26	0·56	0·62	1·35	2·53	0·71	1·48	1·97

	(3) Inflorescence after fruit has set			(4) Inflorescence before the formation of endosperm				(5) Inflorescence of ripe fruit					
	Spathe	Spadix	Fruit	Spathe	Spadix	Fruit	Water	Spathe	Spadix	Husk	Shell	Meat	Water
Moisture	8·22	5·59	6·57	7·11	6·51	4·59	...	8·09	8·82	8·98	8·47	2·93	...
Loss on ignition ...	88·57	88·10	88·69	90·94	88·74	90·66	...	89·43	85·54	87·03	90·51	95·61	...
Insoluble mineral matter	0·58	0·73	0·20	0·71	0·69	0·59	...	1·26	0·69	0·50	0·12	0·10	...
Soluble mineral matter	2·63	5·57	4·54	1·24	4·06	4·16	...	1·22	4·95	3·49	0·90	1·36	...
Total	100·00	100·00	100·00	100.00	100·00	100·00	...	100·00	100·00	100·00	100·00	100·00	...
Lime	0·16	0·55	0·10	0·35	0·35	0·16	4·35*	0·30	0·099	0·089	0·03	0·0055	5·55*
Magnesia	0·12	0·25	0·19	0·17	0·36	0·73	12·15	0·32	0·57	0.19	0·039	0·17	6·55
Phosphoric acid (P_2O_5)	0·11	0·22	0·33	0·08	0·16	0·27	1·83	0·078	0·095	0·064	0·054	0·37	3·70
Potash (K_2O)	0·73	1·25	2·28	0·22	0·58	1·23	50·49	0·092	0·80	0·98	0·32	0·44	31·10

* Calculated on the ash only and not on the original water.

MOISTURE CONTENT OF THE DIFFERENT PARTS OF A BEARING TREE.

	Green weight gms.	Total amount of water		Dry matter	
		Per cent.	gms.	Per cent.	gms.
Inflorescence, fruit before formation of endosperm	1126·5	90·07	1014·28	9·93	112·22
Inflorescence, spadix about to open	1230	86·10	1058·73	13·90	171·27
Inflorescence, fruits after fertilization	315	80·86	254·73	19·14	60·27
Inflorescence, spadix after fertilization	1082	80·34	869·13	19·66	212·87
Inflorescence, female flower buds about to open	124	79·60	98·70	20·40	25·30
Leaf-stalk and peteole (off one leaf)	5532	79·29	4386·25	20·71	1145·75
Inflorescence, spadix of ripe bunch	1186	74·02	877·96	25·98	308·04
Leaflets (off one leaf) ...	3167	70·44	2230·70	29·56	936·30
Inflorescence, about to open, male flowers	287	70·17	201·35	29·83	85·65
Inflorescence, fruit from ripe bunch, average weight of one fruit	1076	56·58	608·90	43·42	467·10
Roots	400	56·38	225·53	43·62	174·47
Stem	148	50·70	75.04	49·30	72·96
Inflorescence, spathe of bunch with fruit set	425	36·84	156·57	63·16	268·43
Stipules (dry)	110	15·08	16·58	84·92	93·42

Potash.—This is required in large quantities by any rapidly growing part of the tree. Such growing parts are always present. The bud or "cabbage" is continually forming new leaves and these leaves are all the time expanding. In the axis of each leaf a flowering branch is normally formed and this in its turn has to grow very rapidly until the flowers expand. Even after this it continues to grow rapidly as the fruit which it carries are swelling and the meat within the fruit is forming.

All these places show a concentration of potash. In the leaves also large quantities of potash are required. This is especially the case in the young plant. Here potash is essential for the process of carbon assimilation, and, since the need of the young plant for the formation of carbohydrates is great, as this is required to build up its tissues, the concentration of potash is greatest in the leaves of the young plant and gradually gets less as the plant grows and the leaf surface is increased. Thus in the 1 to 2 year old plant 41·5 per cent. of the ash in the leaflet is potash. In the 2 to 3 year old plant the amount is 29·4 per cent. In the green or working leaf of the young tree which has not yet reached the bearing stage, there is 4½ per cent. of potash in the leaf stalk and 18 per cent. in the leaflet. In the leaf stalk of the working or green leaf of the bearing tree there is 5 per cent. and in the leaflets there is 13 per cent.

The plant, however, is able to remove a large part of the potash from any working part of the plant as this gets past work. Thus in the young tree not yet in bearing, it is seen that there is 41 per cent. of potash in the ash of the tender leaf, i.e., the leaf which is still growing. In the fully developed green or working leaf there is only 18 per cent., while in the old leaf, which is past work, there is only 13·75 per cent. The same reduction is seen in the case of the leaf stalk. In that of the growing leaf there is 35 per cent. of potash in the ash. In that of the green or working leaf there is only 4½ per cent. and in that of the old leaf which is past work there is less than 4 per cent.

It can thus be seen that the demands for potash are very great and it is one of the most important items of plant food.

Owing to its great solubility the tree seems to be able to move this about to whatever part of the plant it is most required and very little of it ever leaves the tree except in the fruit, and that is to make provision for the needs of the seedling.

Phosphates.—These are required in much smaller quantities than potash, but are just as essential for the proper growth of the plant, since they are essential for the formation of the cytoplasm or living cell contents of the plant. Hence they are found in comparatively large quantities in all growing parts of the plant. Being much less soluble than are the salts of potash, phosphates cannot be removed nearly so rapidly away from parts of the plant where they are no longer required. Thus it is to be noticed that the old leaf and leaf stalk contain nearly as much phosphates as the younger and working leaves. It is to be noticed also how much more sparing the plant is in making use of the phosphates at its disposal. Thus the ash of the "apple" of the 1 to 2 year old tree contains 13 per cent. of phosphates, while that of the 2 to 3 year old tree contains 14½ per cent. Comparing this with the rate that potash is used up, we find that the "apple" of the 1 to 2 year old tree contains 34½ per cent. of potash in its ash, while that of the 2 to 3 year old tree contains only 1·3 per cent. The fact that the older parts of the tree do not lose their phosphates to any great extent, means that in the natural state under which coconuts are grown, these are returned to the soil. But this may not be the case under plantation management. It is probable, therefore, that land which has been under coconuts for a long time is likely to feel the shortage of phosphates more rapidly than that of other plant foods.

Lime.—This was deficient in the soil where the trees were grown from which these samples were taken for analysis, and hence the quantities present in the plant may be much less than would be the case where this was more plentiful.

Lime seems to concentrate in those parts of the plant where the tissues of the tree require to be strengthened. Thus we find it in greater proportion in the leaf stalk, the leaflet, the stipule and in the stalk of the fruit bunch. This is not removed from these parts of the tree when they get past work, and it is therefore lost to the tree till it can again be taken up after these parts, which have fallen to the ground, decay and are again incorporated with the soil.

Magnesia.—In the growing parts of the tree this is found in greater proportion in the leaflets where its presence is necessary for the formation of chlorophyll. It appears, however, to be present in excess of the plant's requirements, since it is also present in appreciable quantities in all old parts of the plant which are shed when no longer required.

These analyses do not include the quantity of nitrogen required for the maintenance of the tree. This, however, is very considerable. In the analyses quoted by Copeland, taking the total of nitrogen, potash (K_2O) and phosphoric acid (P_2O_5) as 100 in the leaf, we find that 24·2 per cent. of this is nitrogen, 57 per cent. is potash, and 18·8 per cent. is phosphoric acid. This presumably refers to what is present in the fully developed green leaf, but the proportion present in the growing parts of the plant, where nitrogen is essential for the building up of the growing tissue, must be very much greater than this.

The fact that the coconut tree is fruiting throughout the year, and that the strain of providing plant food, not only for the formation of the fruit, but also for the development of the tree, is continual, points to the absolute necessity for a well-developed root system if this condition is to be maintained. It must be remembered that any plant food taken into the plant from the soil by means of the roots must be in the form of a very weak solution. This means that the roots of the tree must have a large absorptive surface, which in its turn means that the roots must form a large number of branch feeding roots, because it is only a small area immediately behind the growing point of the root or rootlet which is capable of absorbing water through its surface. To form such a root development, the tree must be able to form, not only a deep root system, but it must also be able to form branch rootlets at a considerable depth. Hence it is that drainage and a well aerated soil are essentials for a permanent crop such as the coconut, which is making such heavy and constant demands on the plant food in the soil and in the soil water. The main roots of the tree must be deep seated, and the branch rootlets must be able to form and survive, not merely in the surface soil, but to a considerable depth. Since the plant food is taken in by the roots in the form of a very weak solution, it is essential also that the root system should have a constant supply of soil water, and this emphasizes the importance of surface cultivation and the formation of a soil mulch. The soil mulch is essential also for the purpose of root pruning. The small rootlets of the coconut are comparatively short lived, and cultivation without damaging the main roots of the tree can be of great value in encouraging the formation of branch rootlets, not only by root pruning, but by the deeper and better aeration of the soil. The soil mulch is essential also for maintaining the supplies of nitrogen in the soil, as a moist well-aerated soil favours the growth of the organisms which are capable of fixing the atmospheric nitrogen in the soil for the use of the crop. The better aeration of the soil increases the rate at which the soil particles weather, and this weathering has the effect of making plant food which was formerly insoluble, available for the use of the plant.

It can thus be seen that much of the "manuring" necessary for maintaining the fertility of the soil is really a question of management. It does not necessarily follow, however, that this is sufficient to supply all that the tree requires, and it is always essential to see that there is no waste on the plantation. The figures given on page 181 show what is lost to the plantation in the manufacture of copra, and what is left on the estate in the shape of husk and shell. As far as the mineral constituents of plant food are concerned, there is no reason why that left on the estate should not all be returned to the land in the form of ash. This contains a large proportion of the potash taken out of the soil, and also an appreciable amount of the phosphates as well as less important elements of plant food, such as lime and magnesia. The lime itself may not be of direct importance, but, being in a caustic state and in a state of fine division, it is probably useful in replacing potash in the soil, and thus liberating this for the use of the crop. It is on account of the use which should be made of the plant food in these products that the system of having driers distributed throughout the estate rather than the central factory system, is advocated. For the same reason the disposal of fallen leaves and other debris from the tree should be burnt in the plantation itself in countries where no marketable use can be made of them.

It is probable that this treatment of the soil will not merely maintain the supply of potash, but will actually enrich the soil in this plant food. Where soil water movement is good, the tree does not merely take plant food from that stored within the reach of its root system but the underground movement of water will often bring in supplies from further afield, and this is more than likely in the case of such a soluble plant food constituent as potash. When the roots of the plant absorb the soil water there is movement from all directions to readjust the distribution of water in the soil, and thus it is that the roots of the plant can take in food from areas which are actually beyond their reach.

In some places quicklime or freshly slaked lime give remarkable results in increasing the yield of the coconut. This is probably largely due to calcium replacing potash in the soil. It will also have the effect of sweetening the soil, which, if it is a coast soil rich in organic matter, may be acid. The coconut appears to be a plant which needs a soil giving an alkaline reaction and this will also favour the development of those organisms which are capable of fixing the nitrogen of the air in the soil.

As regards the actual manures to be used, if it is found necessary to adopt a system of manuring, the grower must to a great extent be guided by what is available. Cattle manure and similar manures are, of course, general manures which supply all that is required in the way of plant food, though possibly not always in the proportions in which they are required by the coconut. There are, however, two objections to its use. Firstly, the carting and spreading of this is expensive; and, secondly, if it is applied in too large quantities there is always the danger of attracting the rhinoceros beetle which lays its eggs in the manure and on which its larvæ feed. The storage of such a manure until it can be applied is always a danger from the same cause. In Ceylon, many advocate the tying of cattle to the base of the tree. In this way the manure is broken up by the animals treading it in, and the urine, being rich in phosphate, is probably the most useful part of the manure, as this is supplied in a soluble form. The objection to this is that the process is slow and the soil mulch is destroyed in the process.

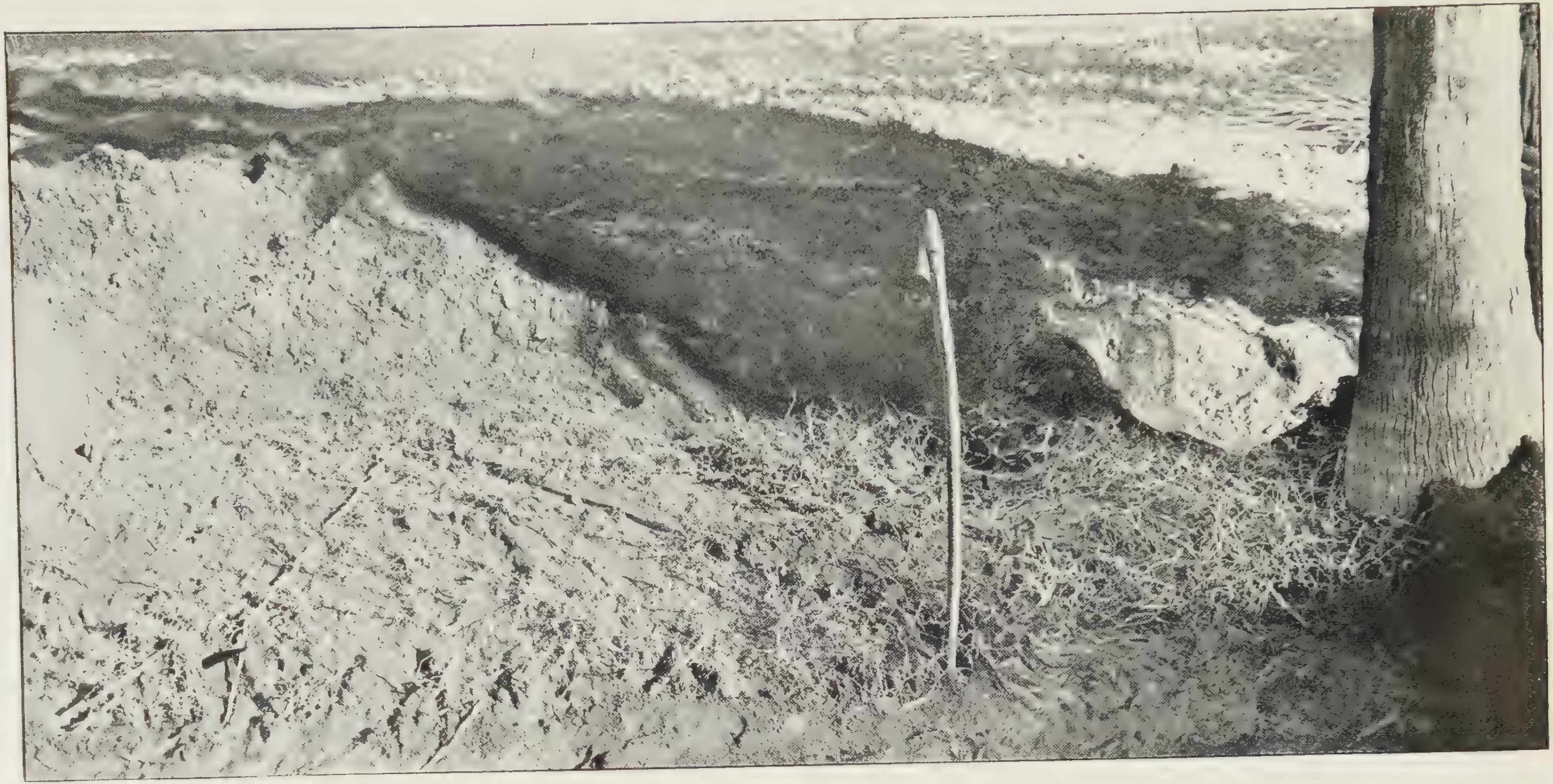
The need for manuring, other than that which is done by returning the ash of the husk, etc., to the soil, will in all probability lie in the use of phosphates. In many coconut-producing countries which are near the sea, the cheapest and best form is in the use of fish refuse. This not only supplies phosphates in a form which is soon available to the tree, but it also supplies a considerable quantity of nitrogen. Each country will have its own fish supplies. On the West coast of India the chief source of fish manure is the sardine, which, after the rains, are caught in such large quantities that it is impossible to utilise the whole catch as human food. The prawn also furnishes large quantities of manure in the form of prawn skins. Most coastal countries where there is a fishing population will have some form of waste product which can be used as a manure for the supply of phosphates and nitrogen. Where a phosphatic manure has to be imported at considerable expense, and where there appears to be no need to supply nitrogenous manures, it will be much cheaper to use other forms of phosphate. What will suit the particular conditions of a plantation is a matter for experiment. Where the soil is inclined to be heavy, or where the soil is rich in organic matter, it is probable that the less soluble forms of phosphatic manure such as bone meal or ground mineral phosphate, will prove to be the cheapest, as, under moist tropical conditions, there is a greater tendency for the phosphate in these to become available to the plant. On light soils, however, it will probably prove cheaper to use some form of soluble phosphatic manure such as superphosphate or basic slag. In this case the choice will depend on where the manure has to be obtained from. It is false economy to buy a low-grade phosphate where high freights and transport charges have to be met, when a high grade or a concentrated phosphate can be purchased at the same unit rate for the soluble phosphate contained therein.

As regards potash manures, if it is found necessary to use these in addition to the resources of the estate for the supply of this manurial ingredient, it may prove more economical to use the more costly, but purer, forms of potassic manures such as the sulphate or the chloride of potash, in preference to "Kainit." The fact that this latter contains considerable quantities of magnesium may detract from its usefulness as a manure, especially where the soils are of igneous origin. The coconut appears to be extremely sensitive to an excess of magnesium salts in the soil.

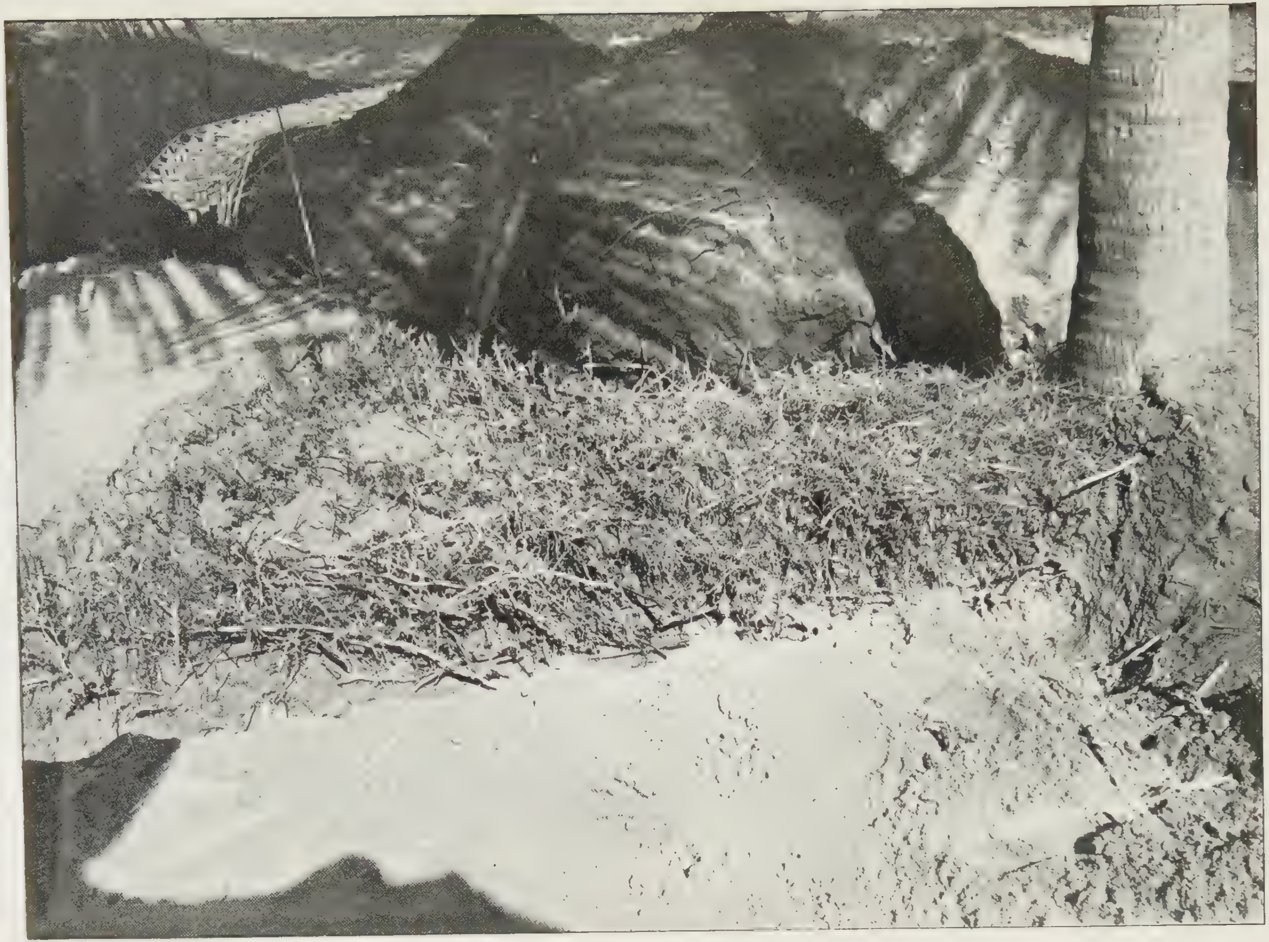
As regards nitrogenous manures, it is probable that it will not be found necessary to expend money on these other than in cultivation and in the growing of green manure crops. If any necessity arises for the supply of further nitrogenous manures, it must be remembered that nitrates are very easily washed out of light soils with free drainage, and that ammonium salts are likely to prove more useful under such conditions.

The Application of Manure.—Except in the first year of the growth of a plantation, any manure which is applied should be broadcasted over the whole area. A glance at Plate II will show the necessity for this even in the second year after planting. If manuring is necessary in the first year, this will be mixed with the soil of the planting hole. It is frequently advocated that when manure is applied it should be spread within a radius of anything from four to ten feet from the stem of the tree. That such a method of manuring is quite wrong can clearly be seen by an examination of Plates XXXVI to XXXIX. These plates show the development of the feeding rootlets under different methods of treatment. In each case the surface loose soil has been scraped away to a depth of some six inches from a segment of the ground radiating from the stem of the tree, and the soil

PLATE XXXVI.



A coconut tree which has not been manured for at least five years. Showing a segment of the ground where the surface roots have been washed out to a radius of eight feet. The effects of previous manuring are clearly evident around the base of the bole.

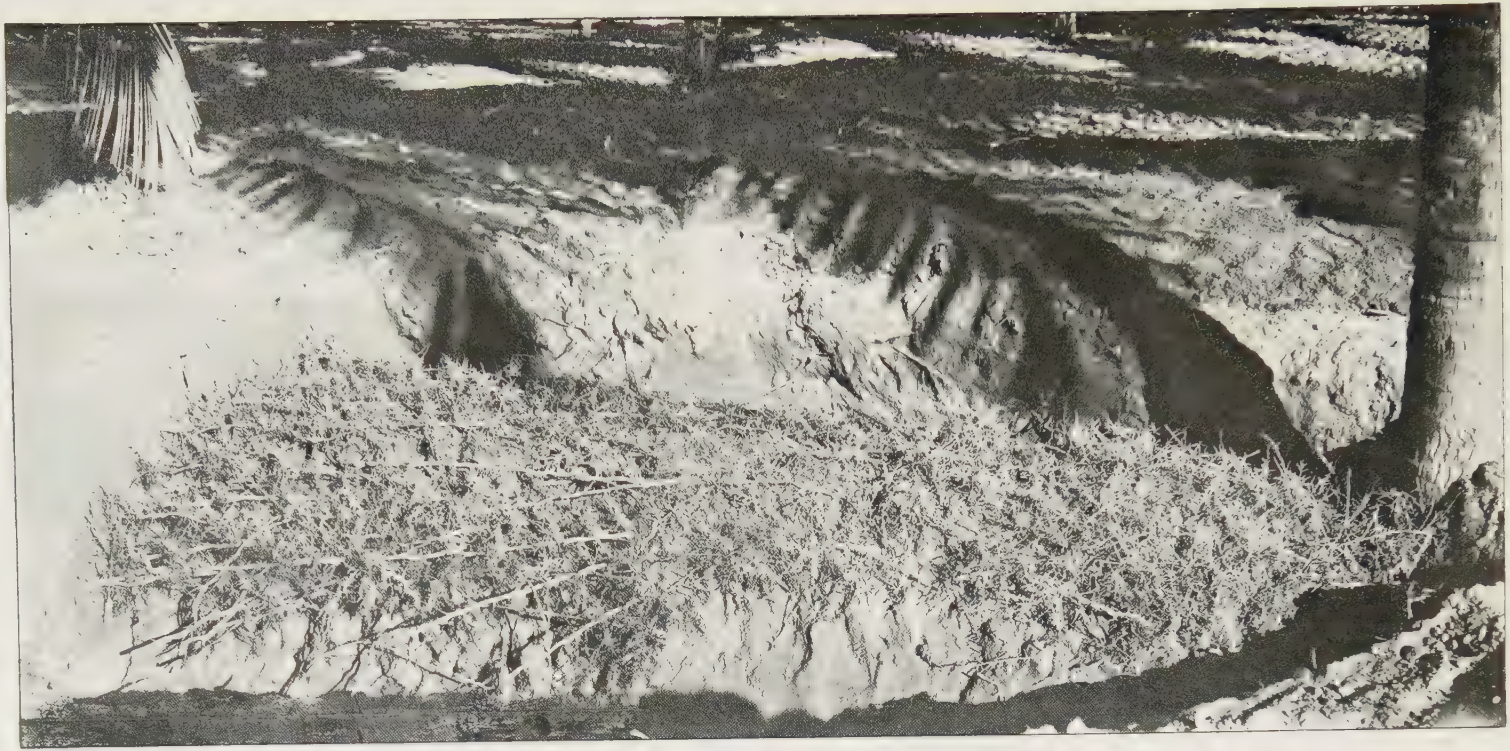


A coconut tree manured to a radius of four feet. Showing a segment of the ground where the surface "feeding" roots have been washed out to a distance of six feet.

below this has been washed away, thus exposing the feeding rootlets. Plate XXXVI represents a tree which has not been manured for at least five years, and the soil has been washed away from the rootlets to a distance of some eight feet from the stem of the tree. A certain development of the feeding roots can be seen to a radius of about four feet, showing where manure had been applied by the previous owners of the trees some five or six years previously. Compare this with Plate XXXVII, where manure has been applied for three successive years within a radius of four feet from the stem of the tree. In this example the soil has been washed away to a distance of six feet, but all the new feeding rootlets are within a radius of four feet from the stem of the tree; these can be distinguished by their much lighter colour compared with the old feeding rootlets beyond this distance. Plate XXXVIII represents the feeding roots of a tree which has been manured for three successive years to a distance of eight feet from the stem with the same total quantity of manure that was applied to the previous tree. The soil has been washed out to a total distance of eight feet, and it is quite clear from this photograph that the feeding rootlets have developed throughout the whole area to which the manure has been applied. Plate XXXIX represents the feeding rootlets of a tree which has been manured for three successive years to a distance of twelve feet from the stem with the same total quantity of manure that was applied to the two previous examples. Here the feeding-root system has been washed out to a distance of twelve feet, and again it is seen that this is a mass of feeding rootlets throughout the whole area manured. It is thus quite evident that if manure is broadcasted over the whole area of the plantation and ploughed in, there will be an unbroken mass of feeding rootlets over the whole area below the level of the soil mulch, instead of having this concentrated within a relatively small area, which would be the case if the manure were only applied within a certain radius from the stems of the trees.

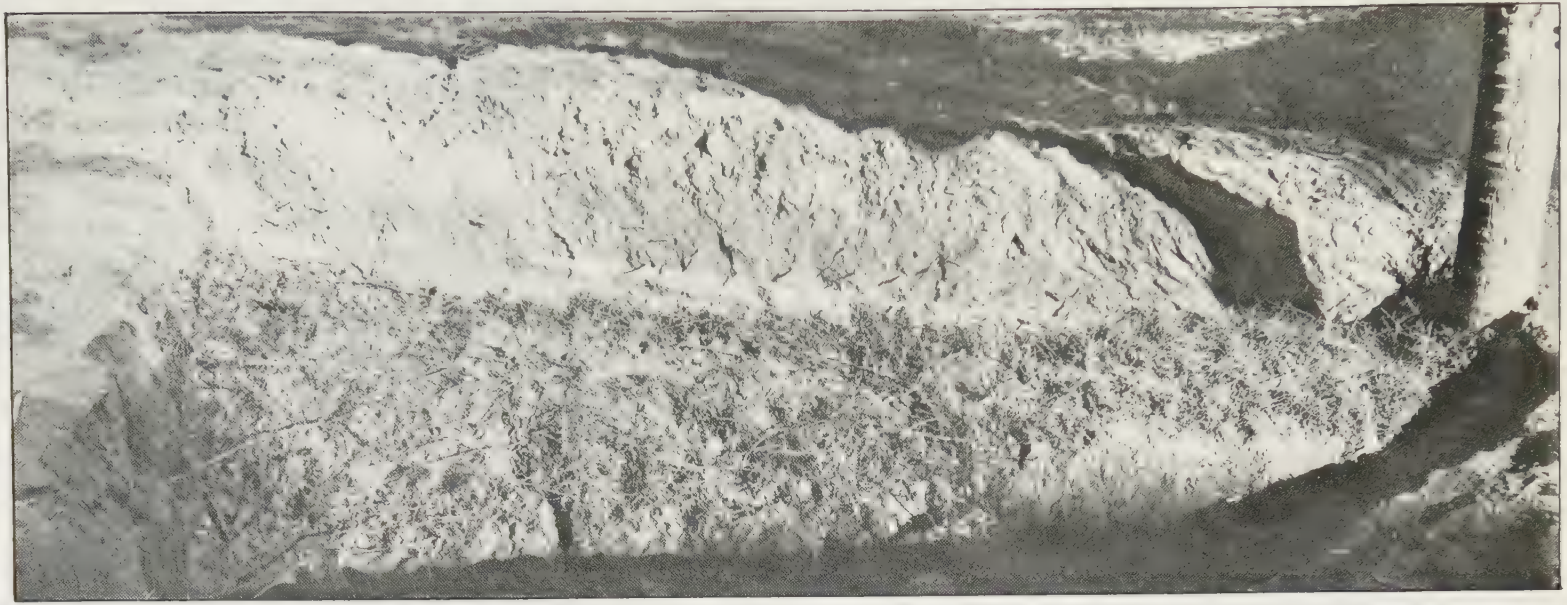
Apart from the question of manuring, these photographs are of interest in showing what a variation there is in the root habit of individual trees. When the manures were first to be applied, the greatest care was taken in the selection of the trees to be manured. To all outward appearances these were as nearly similar as possible, and the cropping registers showed that they were all bearing approximately the same crop of nuts. Yet the main root system shown on Plate XXXVIII is quite different from that of the other trees examined. Here a large number of the main roots come up quite close to the surface of the ground, while in the other examples hardly any are to be seen. In Plate XXXVI main roots are to be seen crossing the washed surface diagonally. These are the roots of other trees. These were to be seen in all the trees examined, but in the other cases they are masked by the mass of feeding roots. This shows how impossible it is to manure individual trees without some of the manure being utilised by the other trees surrounding it. It is thus very difficult to make accurate tests of manures and to find out what manures are required by the crop. If trees are planted on the square system, nine trees (3 by 3) have to be manured in order to get the

PLATE XXXVIII.



A coconut tree manured to a radius of eight feet. Showing a segment of the ground where the surface "feeding" roots have been washed out to this distance.

PLATE XXXIX.



A coconut tree manured to a radius of twelve feet. Showing a segment of the ground where the surface "feeding" roots have been washed out to this distance.

actual results from the centre tree of the square, and sixteen trees (4 by 4) have to be manured to get the results from the centre four trees. Possibly the simplest plan is to manure every fifth row, as well as the row on each side of it, with the particular manure which it is required to test. The yields are then taken from the centre row in estimating the value of the manure applied. The following are the yields of five rows of trees where only the centre row was manured, which show how the trees of the immediately adjoining rows have made use of the manure. The manure, which was a mixture of fish guano and ashes, obtained from the burning of the debris of the plantation, was applied to a strip 8 feet wide down the centre of the middle row. The manure was applied for four successive years at the commencement of the rainy season. It will be seen that the row which received the manure has given the largest increase in yield, but that both the rows immediately adjoining it have given a very appreciable increase,

Yield in Number of Nuts per Tree :—	1918	1919	1920	1921
Rows 1 and 5 (13 trees)	22·0	29·4	36·5	41·8
Rows 2 and 4 (14 trees)	18·4	36·0	36·4	42
Row 3 (6 trees) manured	14·2	29·5	44	43
Yield in Percentages :—				
Rows 1 and 5 (13 trees)	100	134	166	190
Rows 2 and 4 (14 trees)	100	196	198	228
Row 3 (6 trees) manured	100	206	310	303
Taking Rows 1 and 5 as 100 :—				
Rows 1 and 5 (13 trees)	100	100	100	100
Rows 2 and 4 (14 trees)	100	146	119	120
Row 3 (6 trees) manured	100	154	187	160

In testing manured trees against trees which have not received any manure, it must be remembered that cultivation has a great deal to do with the development of fruit and therefore all the trees should receive the same cultivation treatment when a manure has to be tested. Manure firms sometimes offer to supply manure free for trial and send out their own men to apply it. The trees thus manured receive a thorough cultivation while those that the manure is compared with receive none. The whole of the increase is put down to the manure, while the figures given above show that much of this is due to cultivation.

After manure has been applied the planter must not look for immediate results. The first change noticed will be in the leaf development of the tree. The new leaves will become larger, the rate at which they are produced will increase and there will be more on the tree, and, if the manure is what is required the foliage will assume a deep healthy green appearance. The next point to be looked for is the more regular formation of flowering branches and female flowers and, finally, the better setting of the fruit. How far the more rapid development of new bunches can be influenced by manuring is not known. Certainly it has an appreciable effect, because trees which are grown in specially favourable surroundings usually carry a large number of bunches. Thus trees near a dwelling, especially near a fisherman's dwelling, will usually carry several more bunches than a tree grown at a distance from where plant food is plentiful in the soil.

Because trees are not bearing properly, it must not be taken for granted that the soil is lacking in plant food. It may be that the plant food is in the soil, but that the mechanical conditions of the soil are such that the tree roots cannot get at it. Very often it is a case of lack of drainage due to one cause or another. It may be, however, due to the soil being too dry, or it may be due to the presence of a salt pan beneath the surface. All these points should be considered before it is decided to adopt a policy of manuring with manures purchased from without. Such manuring must be looked upon as a last resource. It is expensive and when once started has to be continued. It may also have the effect of making the trees less resistant to dry weather conditions as a large proportion of the available plant food will then be near the surface of the soil.

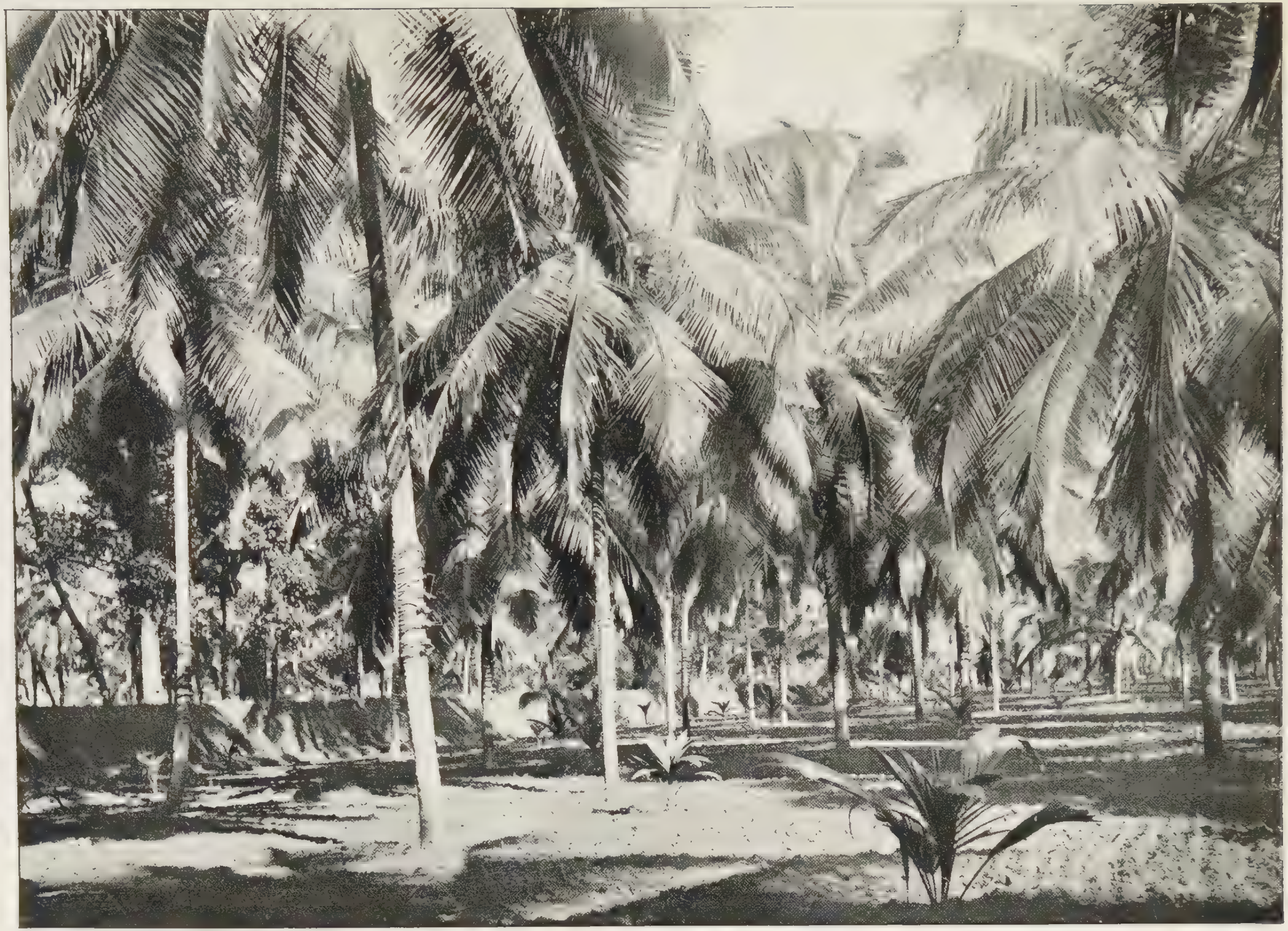
CARE OF AN OLD PLANTATION.

There comes a time in the age of a plantation when the yield begins to flag on account of the age of the trees. In some cases this age may be forty years and in others it may not be till the trees are sixty years old. This will depend on the conditions under which the trees are grown. Under dry soil conditions where the growth and development of the trees are slow, the trees may continue to bear heavy crops till they are sixty years of age, but where the soil conditions are wet, such as in the neighbourhood of backwaters and lagoons, the trees may show sign of old age long before this.

When this time arrives it is necessary to underplant the area with fresh seedlings, alternating with the trees already in existence. For this reason, if for no other, it is very necessary to see that the original planting of trees is carefully spaced.

Although the coconut tree is what is known as a light-demanding tree and does not like to be grown in the shade, the young tree is not so particular. This after all is Nature's way of planting, and the young trees can thrive for a considerable time in the shade of other coconut trees. It is however necessary to give them a good start, and in many cases there is a necessity for manuring; not only to help on the young seedlings, but to prepare for the time when there

PLATE XL



Regeneration. A plantation underplanted with seedlings.

arises a struggle for existence between the old and the young trees. The soil of the planting holes for the young trees should therefore be mixed with manure. This will help the seedlings to become established quickly and get beyond the dangerous age of the unsplit leaf. Before they get beyond this age they are very liable to suffer from the drip of water from the leaves of the old trees, and being grown in the still shade of the old plantation are also more liable to suffer from fungus disease. This manuring, however, causes the roots of the old trees to find their way into the manured soil in which the seedling has been transplanted, and the struggle for existence then commences. Thus in the second year of the growth of the seedling the whole area of the plantation should be manured and this should be continued each year till the younger trees commence to form a stem. It will be found that the yield of the older trees will fall off rapidly as the younger generation of trees gain size and strength, and when the latter have formed a stem the old trees should be cut out. The young trees will not commence to fruit as long as they are in the shade of the old trees. Thus the owner of the plantation must be prepared to forego the crop from the plantation during the interval between the felling of the old trees and the time when the younger trees come into bearing. It is easy enough to make this recommendation on paper, but it is not so easy to carry it out in practice. Some of the more vigorous of the old trees will continue to give good crops and it is not so easy to deliberately cut out such while they still are profitable trees; but it must be remembered that the young trees have much more vigour than the old trees, and when once these are allowed to come into bearing by the removal of the top shade they will very soon make good any apparent loss.

When the old trees are felled the stumps of these should at once be cut out and burnt. The centre of the stem of these stumps is quite soft and full of sap and they will only form breeding places for the much dreaded coconut red weevil and the rhinoceros beetle. After this clearance the planter must decide whether or not to continue the manuring which has had to be given. If the soil is at all fertile further manuring will not be necessary. The removal of the old trees removes at the same time a heavy drain on the resources of the soil and the roots of the old crop still left in the soil will all furnish plant food for the young crop and will tend to make the latter form a deeper root system. The removal of the old crop also will render the operations of cultivation and weeding much easier and more thorough, and this in itself will tend to develop the root system of the young plantation.

PART III.

COCONUT PRODUCTS.

COCONUT PRODUCTS.

THE preparation of coconut products for the market is not an easy matter to discuss, as local conditions vary so much in different countries. It is felt that there is neither need nor useful purpose served in dealing with generalities, nor in discussing different types of machinery manufactured for such work. The efficiency or otherwise of such machinery is a matter to be decided by competent mechanical and chemical engineers.

The matter contained in this part of the book is therefore in the main confined to the methods employed in Southern India. Such methods are largely indigenous, but the fact that the coconut products from the Malabar coast command the highest prices in the world, proves that these methods have their merits, and even if they are not fully applicable to other coconut countries, they may indicate where improvement can be effected.

THE MANUFACTURE OF COPRA.

Copra is the dried kernel or "meat" of the nut, and the method of its manufacture is, to a great extent, determined by the climatic conditions of the country concerned. The methods adopted are: (1) sun-drying; (2) smoke-curing or drying over an open fire; (3) drying by means of artificial heat, either on a heated platform or in an enclosed chamber heated by flues; (4) of recent years vacuum drying has also been tried.

In preparing copra, the main essential is to ensure that the meat is not wetted after the drying has commenced. If it is allowed to get even slightly wet, the resulting copra will not keep, but will go mouldy and rancid. Why it does not go mouldy in the same way if not wetted is not clear, since the meat is quite wet with the "water" of the nut when it is first put out to dry. It may be that the sugar present in this "water" acts to some extent as a disinfectant.

Sun-drying therefore is only possible in countries where there is a dry or moderately dry season, and where there is not much fear of the copra getting wetted by the rain after drying has commenced. If proper precautions are taken, however, sun-dried copra can be prepared even in showery weather.

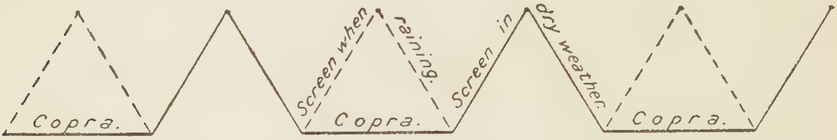
The copra which fetches the highest prices on the markets of the world is the sun-dried copra of the Malabar coast;

and the following description of the general method of manufacture may therefore be of interest. Practically all the coconuts which are made into copra are brought down to the coast for manufacture. It is all the produce of small gardens whose owners sell their nuts to travelling Moplah merchants. The copra-making season begins in November and continues for six months till the next rainy season commences. Two grades of nuts are recognized. The first grade are those nuts which have been harvested during the rainy season and stored, and the second grade are the nuts sold as they are picked from the trees. These travelling merchants either make copra themselves when they return to the coast, or sell the husked nuts to bigger men who are professional copra manufacturers. These latter have permanent drying floors which are fenced in with split bamboo fencing to keep off dogs, &c., and are covered over with coarse netting which keeps off crows and other birds which have learnt to eat copra. Clean sand is spread on the floor of this drying yard. The husked nuts which are to be made into copra are split in half. This is done by holding the nut in the left hand and giving it a sharp blow with a billhook across one of the three ribs on the shell of the nut. Unless the blow hits one of these ridges the shell breaks with an uneven fracture. The "water" in the nut is allowed to fall on the ground. The half nuts in the shell are then placed close together on the drying floor with the meat uppermost. Within two days the meat will have contracted away from the shell, and, if the half nut is inverted, will usually drop out. If it does not come out or is not quite loose it is eased out with a wooden scalpel.

The half kernels are in the evening placed in a heap and covered over with matting to protect them from the dew. In the morning they are again spread out on the drying floor and in the evening are again collected, heaped and covered over. This process is repeated until the copra is dry and brittle, which usually takes from three to five days after the kernels have been separated from the shell. When the nuts are being split any which are not sound or have commenced to germinate are put to one side as these will never make first-grade copra. The nuts which have been stored give the best quality of copra. These are partially dried before ever the nuts have been husked and frequently the meat has already shrunk away from the shell when the nuts are split. In such copra the kernel will retain its shape and will retain the sharp edge where the meat has been broken. The outer skin of the meat is a dark brown colour. In the case of freshly picked nuts, the meat as it dries curls up and the edge becomes rounded as the meat shrinks and the skin of the meat is a red-brown. The storage of nuts in the husk is quite a common practice. If the plantation is big enough, specially constructed stores are built. These buildings are erected on raised masonry platforms. The sides of the store are made of stout laths of wood—usually coconut wood—with a space of about 4 inches between each lath. These are fixed horizontally into wooden pillars. The whole is covered with a tiled roof having wide overhanging eaves. During the rains a fire is kept burning at the windward end of the building so that the hot dry air blows through the store and prevents the nuts from germinating. If only a small store is required, this is built in a similar manner over the kitchen of the house.

As regards the keeping qualities of copra, the professional makers state that copra made from nuts from inland gardens is of better quality than that made from nuts grown in the vicinity of backwaters or lagoons, and that it keeps better. They say also that the same is true of copra made from nuts from old trees compared with that from nuts from young trees.

In the northern parts of the Malabar coast no special precautions are taken against rain, as in the dry weather this is of rare occurrence, but, in the southern parts, showers are liable to occur, and here special precautions are taken so that the drying copra can be covered over if rain is seen or heard approaching. In a coconut tract, the rain falling on the leaves of the trees can often be heard some minutes before it reaches the spot where one is standing. Here the copra is arranged in parallel strips on the drying ground, leaving similar alternate strips vacant. These strips are from 8 to 10 feet wide. Large screens some 15 feet long and 8 to 10 feet in width are made. These screens consist of a split bamboo framework which holds in position overlapping "cadjans" or leaf mats which will turn the rain. When the weather is fine, these screens form a long pent roof, covering the vacant strips; but as soon as there is any indication of rain coming, men who are working in the drying ground reverse these, so that they form a pent roof over the drying copra. Care must be taken, however, to see that rain does not drive into the end of the tunnel, and that it does not get in at the ridge. The following diagram represents a section across the strips and indicates how the screens are used:—



Smoked copra is made by placing the meat of the nut on grids over an open fire, either in an open shed or in a closed, but ventilated, chamber. The ordinary drying shed or kiln is an improvement on this, as the smoke does not get at the copra as it is drying. This consists of a platform some 40 by 40 feet, supported on four retaining walls and inner walls or pillars at suitable distances. This platform is either made of cement slabs or of reinforced concrete. There is a space of some 4 feet between the level of this platform and the ground. In the front of the building at ground level a furnace, suitable for burning coconut husks and shells, is built. From this furnace there are two flues which branch off diagonally to the middle of the side walls, and here there are chimneys to create the necessary draught and to carry off the smoke. This heats the whole of the drying floor, more especially the area towards the front where the furnace and the flues are situated. The whole is covered with a roof which is usually thatched with "cadjans," and which at the eves is some 5 feet above the level of the drying floor. The nuts after being split in two are placed on the rear half of the drying floor, where they are allowed to slowly dry. When they are dry enough for the kernel to come away from the shell, these latter are removed, and the half kernels are then placed on the front half of the drying floor. The copra is considered to be ready in about forty-eight hours after drying is commenced. This form of dryer can be made on the estate, and is quite efficient for dealing with a limited quantity of nuts, and is useful when an estate first commences to come into bearing.

Other types of hot-air dryers have the flues arranged within the chamber where the copra is drying, and the copra is placed on trays one above the other. In such dryers top ventilation is essential to take off the moisture-laden air produced by the drying of the meat.

The manufacture of copra is by no means perfect, and it is probable that it would be well worth while spending money on further research into the subject of its manufacture. The fresh meat of the coconut contains 45 per cent. of water and the greater part of this has to be driven off in the manufacture of the copra. If this is not done the copra will very soon go mouldy, which means that free fatty acids will be formed and that the oil will go rancid. Ceylon has shown that much improvement is possible in its manufacture, and there is little difference now in the price of "Ceylon" compared with "Cochin" copra. That of the Straits and Malaya is still a good way behind Ceylon, and that from the Pacific Islands is a good way behind the Straits.

Has the slow rate of drying, which is the case with the sun-dried copra of the Malabar coast, anything to do with its keeping qualities? It is quite possible that the rapid drying with artificial heat may not dry the copra right through, that the outside of the copra is much dryer than the inside and that the moisture which is imprisoned inside cannot escape at the moment, but is gradually given off when the copra is stored. Copra may leave the estate in apparently perfect condition, but by the time that it is shipped it has developed mould. It may be that if the copra were given a final drying on the estate after it has been cut up for packing for export, this imprisoned moisture, if it is present, would be to a great extent driven off.

Is it possible that the mineral ash constituents of the copra have anything to do with its keeping qualities? It has already been mentioned that the professional makers of copra on the Malabar coast state that nuts from the rich backwater soils do not make such good copra as that from the dryer and less fertile plantations in the interior. Even the best copra is hygroscopic and the Malabar copra has to be shipped away from the coast before the rains set in, otherwise it very rapidly moulds. It may be that some of the mould is caused by the export stores not being properly constructed and ventilated.

The development of moulds on the copra can be considerably checked by fumigation with sulphur, but it is possible that the consumers of copra would object to the presence of sulphur on the copra. If so, is there any other method of disinfecting the surface of the copra against fungi which would not be considered objectionable?

Copra is in most cases the final product of the estate, and it is the quantity and quality of this, which is prepared from a given area which should be shown as the final yield. It is all very well saying that the yield is so many nuts per tree, but the nuts vary in size according to the management of the plantation, besides which there are always a proportion of them which are unsound. Some may not have fully formed while others may have germinated before they have been harvested. All factory records should show therefore the yield of graded copra from definite blocks on the estate.

COCONUT OIL.

Coconut oil is being increasingly manufactured in the countries of production, and it is quite probable that at some future date, oil rather than copra will be manufactured on the estate itself. It is possible also that coconut oil will in the future be used in much larger quantities by the densely populated countries of the East and that the Western markets will not be the only ones open to the grower. An an indication of this it may be mentioned that more than 3,500,000 gallons, or about 70 per cent. of the coconut oil exported from the West coast ports of Southern India, goes to Indian ports in other parts of India, and this is the highest priced coconut oil in the world. Within the last five years the position in the Philippines has entirely changed, as indicated by the following figures :—

	Average copra exports in 1,000 kilos	Average coconut oil exports in 1,000 kilos
1911-1915 ...	118,730 ...	6,215
1916-1920 ...	61,015 ...	108,201

It is quite possible, therefore, that such a change may well take place in other coconut producing countries, especially seeing that such large sums are lost on account of the inferior quality of much of the copra when this reaches its final market.

Whether the final method of oil extraction has yet been discovered remains to be seen. So far, for all commercial extraction, the coconut meat has first to be converted into copra and the oil extracted from this. It is quite possible that methods of extraction will be evolved whereby the oil is extracted direct from the fresh meat. If such a method is evolved, it would probably mean a considerable improvement in the quality of commercial coconut oil.

On the Malabar coast coconut oil is known as "the ghee (clarified butter) of Malabar." Every household uses coconut oil for frying and other culinary and domestic purposes, and here the housewives are very particular as to the quality of the oil which they use. The more particular prepare this for their own use direct from the fresh coconut. This is split in two and the fresh meat is grated. This is then macerated with water, the oil forming an emulsion, which is sometimes referred to as "coconut milk." This is then boiled and the oil which floats to the surface is skimmed off. Such oil has the sweet smell and taste of the fresh coconut and it will keep for a considerable time. The second best grade of oil is prepared from specially prepared copra. Selected ripe nuts are split and dried in the ordinary way, and the fresh copra is then taken to the oilmonger who extracts the oil in the country oil mill or "chekku." This consists of a large wooden mortar which is firmly fixed in the ground, and a large wooden pestle, which revolves in the mortar, being firmly pressed against the side of the mortar by a lever. This lever is attached to a gear which is driven in a circle by a pair of bullocks. The oilcake or "poonac" is thus pressed to the sides of the mortar and the oil collects in the centre and is extracted from the mill by being soaked up in a cloth and squeezed into a receptacle. These mills are quite efficient and from 55 to 60 per cent. of the weight of the copra is recovered as oil. It is oil of this quality which is usually retailed in the shops. In the export towns the manufacture of oil has become a factory industry, and the country mill or "chekku" is replaced by engine-driven mortar mills. These work on much the same principle as the "chekku" except that the mortar, which is made of cast iron, revolves instead of the pestle. Each of these mortar mills requires about 3 B.H.P. to drive it and is capable of dealing with some 50 lb. of copra per hour.

There are, however, numerous methods of oil extraction by power, one of the most recent being the "Anderson oil expeller" which has practically replaced all others in the Philippines. These are also to be seen in other coconut producing countries.

One of the main objections to the manufacture of oil in the country of production is the cost of packing for export and the high freights charged on this class of cargo. The other main objection is in the import tariffs imposed in many of the markets where this is sold. In the Philippines, where the export of oil has developed to such large proportions, the difficulty of packing for export has been overcome by the carriage of oil in bulk in tank steamers. These are fitted with steam pipes in the tanks so that the oil can be liquefied when this reaches its destination. Where the export of oil is only in limited quantities, it is usually shipped in barrels. This is a very costly method of packing, for, not only is the initial cost of the barrels great but it is awkward cargo to stow and is apt to shift in transit. Moreover, if the staves of the barrels are again shipped out, which is often done, there is always a quantity of coconut oil in the wood of these which by the time that they reach their destination has gone rancid. This rancidity taints the next consignment of oil which is shipped in the same barrels.

It is possible that at some future date cool storage may be adopted for the ocean carriage of coconut oil. It is possible that advantage might be taken of the high temperature at which coconut oil solidifies and that the oil might be carried in the solid form. The oil solidifies at a temperature of 68° F., and thus only moderately cool storage would be necessary for its carriage.

THE MANUFACTURE OF COIR.

The word coir is derived from the Tamil or Malayalum "kavur" (pronounced cower), which means cord, but in commerce has come to mean the fibre derived from the husk of the coconut.

The finest coir in the world comes from the Malabar coast, and from the Laccadive and Divi Islands off that coast.

The best quality of coir is made from the husk of ripe nuts which have been harvested before the husk has ripened and dried. Though fibre can be extracted by mechanical means within a very short time, to get the smooth, light-coloured fibre the husks have to be soaked in water or retted. This retting takes from eight months to a year. The quality of the fibre is judged by the colour, which should be a golden yellow. If the husk is too dry when the nuts are harvested, this golden colour can never be obtained, and the fibre will always be a red-brown. The colour is very dependent also on the conditions under which retting is done.

The process of retting consists of digging a pit some six feet deep in or near the edge of the backwater. This pit is then filled with husks up to two or three feet from the surface. The husks are then covered over with plaited coconut leaves and the pit filled up again with mud. This is left till the husks are considered ready for the extraction of the fibre.

They must not be left for more than a year, otherwise the fibre loses colour, strength and brilliancy. To get the best results the site chosen for the retting pit should be within reach of the action of the tide, and the soil in the backwater should have a large admixture of sand. If the water is stagnant, or the mud contains too much clay, the fibre will be weak and of a dull grey colour, and will only command a low price. It is apparent, therefore, that a certain amount of aëration is necessary to assist the bacterial action in the proper retting of the husks.

The extraction of the fibre and the spinning of the yarn are purely cottage industries. The removal of the husks from the retting pit is no pleasant task on account of the stench which arises from it when opened. After the removal and the washing of the husks to remove the dirt from the retting pit, the outer rind of the husk is removed. The rest of the work is done by women usually at their own homes. This consists of beating the husk on a board or stone with a wooden mallet. This separates the pith of the husk from the fibre. The fibre is then washed in clear water and afterwards beaten with sticks to shake out any small particles of pith which remain. Without retting it is impossible to get rid of this pith from the fibre, and its presence on the fibre makes it impossible to spin an even yarn. After the final beating the fibre is spread out in the sun to dry. In Malabar it is usually reckoned that the husks from 600 nuts are required to give a hundredweight of clean fibre.

The spinning is frequently done by the women who beat out the fibre, but more often the extraction of the fibre is given out on contract, and the fibre is returned to the merchant, who sorts this into grades according to colour, and then gives the graded fibre out for spinning into yarn. If the women who beat the fibre also spin it, it is much more difficult to get an even-coloured yarn when this is bulked.

In some places women spin the yarn by twisting it in their hands, and it is extraordinary how adept they become in this work and in producing a yarn of even thickness. In other parts spinning wheels are used. With these, three women and a boy can make one hundred lengths of yarn each 30 feet in length in a day. One woman is employed in making the fibre into rolls or "sliver." The boy is employed in turning the handles of two spinning wheels, each of which is made to spin two lengths of yarn at the same time. The other two women each feed two strands of yarn, one in each hand with the rolls prepared by the third woman, and they walk backwards as the yarn lengthens. For making coir twine three of these strands are twisted together in a rope walk. For export this twine is again graded and rewound, the 30-foot lengths being spliced into one continuous strand. This is made up into hanks of 450 yards length and these are pressed and baled for export. Much, however, of this twine is worked up into manufactured commodities in the country. Some of it is made into coir matting, some is woven into doormats, which is merely matting with a pile woven into it and might be called coir velvet; some is made into binding braid, some is made into coarse netting for making bags for the collection and packing of produce, some of it is even made into belting for driving machinery.

The coir industry in South India is considerable and the value of the export of this commodity represents nearly 30 per cent. of the value of coconut products exported from West coast ports.

There are probably few commodities which have such a wide range of price according to quality. At the time of writing, coir on the English market varies from £20 to £37 a ton according to quality. Yet it is all made from the husk of the coconut, and presumably the fibre in the husk was all of the same quality originally. Considerable quantities of coir are now made from the fresh husk by machinery, but the fibre in this can never have the same colour and smoothness as that obtained from the retted husk. Here again there seems to be scope for research work to be carried out ; for it is quite possible that retting can be done in properly constructed tanks and that the bacterial processes which are necessary for the breaking down of the pith in the husk can be controlled and regulated. It is possible also that the period of retting could be considerably reduced. If this is proved possible, then it is likely that very much less costly machinery would be required for beating the husks and very much less power would be required to work this machinery than is at present required for extracting the fibre from the fresh husk. A much better quality of fibre would be produced which would command a much better price.

The Indian methods as they exist are only possible in countries where there is a dense population, and where labour is sufficiently cheap to do the work by hand. The methods also are extremely wasteful of the valuable plant food which is contained in the husk, as the following analyses show :—

	Fresh coconut husk	Retted coconut husk	Cleaned coir	Dust obtained after beating out the coir
Calculated on dry weight—				
Nitrogen	0·53	0·74	0·06	0·87
Ash	6·71	8·07	1·46	33·21
Containing—				
Lime	0·33	0·37	0·09	0·55
Magnesia	0·21	0·57	0·16	0·89
Phosphoric acid	0·111	0·076	0·032	0·137
Potash	2·65	0·15	0·08	0·20
Silica	1·22	2·57	0·66	22·03

These samples were all obtained from the same neighbourhood and as far as could be ascertained the husks which were being retted were from trees grown under similar soil conditions as were the samples of the fresh husk. It is evident that practically all the potash has been leached out and it is probable that there has been a loss of phosphoric acid. It is interesting to note, however, how the nitrogen has been retained. Anyone who has been present when these retting pits are newly opened would find it difficult to believe that rapid denitrification had not been taking place.

Besides the loss of plant food by this process of retting there is the question of the general health of the people to be considered, and on medico-sanitary grounds the presence of all these retting pits in a densely populated country cannot be considered good for the general health. Though these retting pits are too foul to breed the *Anopheles* mosquito, they are quite capable of breeding the ordinary *Culex* which can convey such diseases as elephantiasis, and possibly this explains why it is that this disease is so prevalent in places where these by-products of the coconut are prepared.

TAPPING.

This is the term applied to the operations connected with the extraction of the juice of palms. In the case of some palms such as the coconut, the Indian palmyra and the Indian sago palm (*Caryota urens*) it is the tender inflorescence which is tapped, while in the case of others such as the wild date, and in East Africa, the African palmyra, it is the tender stem which is tapped.

Whether the term tapping applies to the actual drawing of the sap from the tree, or whether it refers to the operation of tapping or beating the spathe, which is usually done in the case of those palms where the tender inflorescence is tapped, is not clear.

The juice which is obtained from all these palms is very rich in sucrose or cane sugar, and at tropical temperatures this very quickly ferments. Such fermented juice is known as "toddy." This when fresh may be used as a beverage or it may be distilled. The spirit obtained from distillation is known as "arrack."

If fermentation is prevented in the collecting vessel, the juice is known as "sweet toddy," and when this is boiled down it gives a raw sugar or "jaggery." The fermentation can be checked either by sterilizing the collecting vessel, which is done by burning it out after emptying the juice, or it can be done by adding slaked lime while the juice is being collected. This is done by smearing the inside of the collecting vessel after this has been emptied and the vessel scrubbed and washed out with water.

In India there are special castes whose hereditary occupation is the tapping of palms for the collection of "toddy." In Southern India these are the Shanars of the East coast and the Tiyas of the West coast, and it is natural, therefore, that the practice of this art has reached a high state of efficiency. It is not always an easy thing to get the sap to flow. Some coconut trees, though they will bear good crops of nuts, will never yield their flow of sap. Tappers from one part of the country are often unable to get a flow of sap in another part of the country. Thus there are all sorts of variations in the exact methods of tapping adopted, and there are all sorts of superstitions connected with the operation. Certain days of the week and month are considered inauspicious to commence tapping a tree, while others are considered auspicious. Often special mantrams are said before commencing operations. In many places the thigh-bone of the spotted deer is used for beating the spathe, and in one part of Travancore this has to be consecrated at intervals by killing a fowl and mixing the blood of the sacrifice with gravel, which is then rammed into the hollow of the bone and left there. This is supposed to retain its efficacy for about six months, when the ceremony has to be repeated.

Not only is there this variation in the readiness with which trees will give their sap, but there is a seasonal as well as a daily variation in the amount of sap which flows.

Sap also always flows more readily at night than in the day time. During the rainy season, when it is cloudy weather, the flow of sap is small. When fine weather ensues, the flow of sap increases, but as the dry season continues the flow gradually falls off again. The flow of sap also varies with the state of the spathe which is being tapped. At first when the tip of the spathe is being tapped, the flow is small, but this gradually increases and reaches its maximum when that part of the spathe is being tapped where the female flower buds are situated.

The quality of the juice, i.e., the percentage of sucrose which it contains, also varies. Young trees give a weaker juice than old trees. The first juice which commences to flow is not so rich as that obtained from the lower part of the spathe.

The tapping of trees is usually continued for a period of six months if these are found to yield a profitable quantity of juice, and each successive spathe, as it is ready, is tapped. Thus there may be three spathes being tapped at the same time on the same tree. From observations made, however, the oldest spathe very soon fails when the third spathe commences to give its regular supply of sap. At the end of six months the trees are usually given a rest from tapping. If continued for a longer period it is said to weaken the trees. Tapping the trees for six months, however, stimulates the tree, and frequently owners allow tappers to tap their trees at a more or less nominal rent, as this stimulates the tree subsequently to bear fruit. One will always notice that trees which have been tapped bear very well afterwards.

The yields of toddy from profitable trees will be about two to three quarts a day. If it is "sweet toddy," this will give about 20 per cent. of its weight as raw sugar when the juice is boiled down.

The simplest method of tapping is that found in the north of the Malabar district. The spathe to be tapped is not fully developed and the right stage of development is roughly judged by the state of the older spathe. If this is ready to burst, then the one younger than this is approximately ready for tapping. The spathe to be tapped is then tied very tightly at intervals of 1½ to 2 inches all along its length. On the following day, the end of the spathe is cut off sufficiently low down to cut off the end of the inflorescence within. If the spathe is at the right stage for tapping the exposed surface of the inflorescence should turn a golden yellow colour after a short exposure to the air. The cut end of the inflorescence is then pounded with the wooden or horn handle of the knife and a piece of the stipule of the coconut leaf is then tied over the cut surface. This operation is repeated for three days morning and evening. During the next three days the cut surface is scraped with the back of the knife blade in order to remove the bruised portions on the cut surface. If the operation is successful the sap will commence to flow on the seventh or eighth day after the operation started. On the tenth day the flow will be sufficient to collect the juice, and a vessel (in India an unglazed earthenware pot is used) is hung on to the end of the spathe to catch the juice. Before attaching the vessel about 2 inches of the inner spathe is removed from the cut end to expose the inflorescence. The latter is then tied with a piece of tender coconut leaf and at the same time a small projecting piece of coconut leaf is tied to the under side to direct the flow of sap into the pot. The cut surface is then rubbed with the tender leaves of *Sporosa lindleyana* and well washed. The leaf of this plant is used all along the West coast by tappers and it is said to assist in preventing the wound from healing up. After the flow of sap has commenced the same treatment is continued night and morning. Some tappers will do this in the middle of the day as well. Juice is collected night and morning, and clean pots which have been well washed and scrubbed are hung in place of the used ones. If "sweet toddy" is being drawn the insides of the pots are, in addition, smeared with lime. One man can look after twenty trees, and each spathe will last for about six weeks to two months according to the skill of the tapper. Whether this method of tapping is capable of more general application or not is not known. In the course of some tapping experiments which were being carried out two experienced tappers were engaged from here and taken to a plantation some thirty miles to the north, but, following the methods which they were accustomed to, neither of them could get any flow of sap.

In other parts of the West coast the operation differs. The difference lies chiefly in the treatment of the spathe before the sap commences to flow. The right time to commence the operation seems to be of great importance. If the previous spathe has not been tapped this is judged by its development, otherwise the tapper has to use his judgment, which is usually based on the shape of the spathe to be tapped. If this is slightly swollen at the base, which is caused by the swelling of the female flower buds within, this is said to indicate the right stage. The first operation, as before, consists of tying the spathe tightly all along its length at intervals of 1½ to 2 inches. The outer surface of the spathe is then tapped or beaten all round. For this the thigh-bone of a deer is used. The tip of the spathe is cut off exposing the inflorescence. This is to ascertain whether the spathe is ready for tapping or not, and this is judged by feeling the male flowers. If these are moist or "milky" then tapping has been commenced at the right time. If they are dry and meally then the right time is passed. After the spathe has been beaten the cut end is beaten with the handle of the tapping knife, though in some places the cut end is merely kneaded with the hands. This beating or kneading is to check further growth of the inflorescence, and the operation is repeated every other day. At the end of six days 3 or 4 inches of the end of the inner spathe are cut off exposing the end of the inflorescence, which is tied in the same manner as described before. The sap should commence to flow at the seventh day and within three or four days the flow should be sufficiently strong for fixing the pot to collect the juice. The subsequent operations consist of shaving off a thin slice from the exposed end of the inflorescence, beating it and scraping off the bruised material on the surface. This is usually done twice a day, but in some places it is done three times.

Much depends on the skill of the tapper both in making the juice commence to flow and in the quantity of juice which is collected afterwards. A skilled tapper will make a spathe last three months tapping twice a day while a poor workman will make it last only a month.

For the manufacture of raw sugar the "sweet toddy" collected in the evening is boiled as soon as it is brought in and then left till the morning toddy is collected. This is then added and the juice is boiled down till it becomes a saturated solution, when it is poured out into moulds. As the albumenoids in the juice coagulate at the surface it is apt to froth up. When this occurs a few drops of coconut oil or a little grated coconut is added and the froth subsides. The raw sugar is usually of a dark colour on account of the excess of lime present in the juice, but in India this cannot be prevented as liming of the pots is compulsory unless special licences are taken out for tapping fermented toddy.

Experiments recently carried out by Dr. R. V. Norris, the Government Agricultural Chemist, Madras, show that considerable improvement is possible in the making of raw sugar. The filtering of the juice through sand filters renders the juice much cleaner, and the addition of small quantities of alum to the juice precipitates the lime and magnesia, which renders the raw sugar much less deliquescent, so that it is not only of a much better colour but will keep hard for a reasonable length of time. Very fair crystallized sugar can be prepared by centrifuging the raw sugar.

The juice of the palm compares very favourably with that of the sugar cane, not only in the amount of sucrose present but in the purity of the juice.

The tapping of palms for sugar is a very considerable industry throughout Southern India and is the source of the major portion of the sugar consumed there.

The fresh fermented toddy is useful as a substitute for yeast for bread making, while vinegar is made from this as well.

MINOR INDUSTRIES.

Most of these are only of interest in the rural and domestic economy of the people of the country, but there are, as has already been mentioned, parts of the coconut tree which might well repay further research into their uses.

The shell of the nut, for example, furnishes a very fine sample of charcoal, which possesses the property of being able to absorb gas very freely. For this purpose it was extensively used for gas masks during the war. When burnt it gives a great heat and is always used by goldsmiths in Southern India for their work.

The fibre of the inner spathe is probably well worth investigating. It is largely used in the raw state in South India in place of rope for tying, especially for outdoor work which has to stand the weather. The fibre of the fruit stalk is an excellent straight brush fibre and it is probable that a market could readily be found for this. The leaf-stalk also contains a fairly good fibre, but whether there is any future for this is doubtful.

INDEX.

A

PAGE

Absence of branches ... 37
Absorptive area of roots ... 1, 26
Adaptability of the coconut palm ... 87
Aeration, soil ... 202
Aeration, soil, effects of on development of root system ... 3
Age, colour of roots an indication of their ... 17, 18
Age of tree for selection of seed ... 96
Age of seedlings when ready for transplantation ... 110
Air spaces in roots ... 27
Alkaline soils ... 91
Analyses of different parts of the coconut fruit at different stages of development ... 173, 174
Analyses of fruit in different countries ... 182, 183
Analyses, comparison between those of a " barren " tree and a bearing tree ... 184, 185
Analyses, percentage of ash to dry matter in a one-year-old tree ... 187
Analyses, percentage of ash to dry matter in a two-year-old tree ... 187
Analyses, percentage of ash to dry matter in a young tree ... 187
Analyses, percentage of ash to dry matter in a bearing tree ... 187
Analyses, percentage of dry matter to total green weight, one-year-old tree ... 186
Analyses, percentage of dry matter to total green weight, two-year-old tree ... 186
Analyses, percentage of dry matter to total green weight, a young tree 186
Analyses, percentage of dry matter to total green weight, a bearing tree 186
Analyses, Lime percentage in ash in a one-year-old tree ... 190
Analyses, Lime percentage in ash in a two-year-old tree ... 190
Analyses, Lime percentage in ash in a young tree ... 190
Analyses, Lime percentage in ash in a bearing tree ... 190
Analyses, Magnesia percentage in ash in a one-year-old tree ... 191
Analyses, Magnesia percentage in ash in a two-year-old tree ... 191
Analyses, Magnesia percentage in ash in a young tree ... 191
Analyses, Magnesia percentage in ash in a bearing tree ... 191
Analyses, phosphoric acid percentage in ash in a one-year-old tree ... 189
Analyses, phosphoric acid percentage in ash in a two-year-old tree ... 189
Analyses, phosphoric acid percentage in ash in a young tree ... 189
Analyses, phosphoric acid percentage in ash in a bearing tree ... 189
Analyses, potash percentage in ash in a one-year-old tree ... 188
Analyses, potash percentage in ash in a two-year-old tree ... 188
Analyses, potash percentage in ash in a young tree ... 188

PAGE

Analyses, potash percentage in ash in a bearing tree 188
Ants 147
"Apple" 78
"Apple," structure of 79
"Apple," colour of 81
Application of manure 124, 206
"Arrack" 64, 235
Arrangement of leaves 27, 38, 39, 98
Arrangement of leaves, importance of 38
Artificial pollination 54, 104
Astringency of roots 28
Attachment of leaflets 47

B

Bad drainage, effects of 88
Bad type of tree 99
Bad type of seedlings 106, 111
Bag worms 148
"Barren" fruit 66
Barren trees and bearing trees, comparison in analysis of ... 184, 185
Baskets made from coconut leaves 48
"Beard" of the nut 79
Bearing capacity, influence of root development on 4, 10
Bearing register, maintenance of 102, 103
Bearing tree, percentage of ash to dry matter 187
Bearing tree, percentage of dry matter to green weight 186
Bearing tree, percentage of lime in ash 190
Bearing tree, percentage of magnesia in ash 191
Bearing tree, percentage of phosphoric acid in ash 189
Bearing tree, percentage of potash in ash 188
Bermuda grass 114
"Bleeding" disease 89
Bole, moisture supply to 48
Bole, root-producing area of 6
Bordeaux-resin-soda spray 148
Branches, absence of 37
Branch, flowering 50
Branchlets of flowering branch 51
Branching of "water roots" 21
Branch roots 2
Branch roots, size of 2
Branch rootlets 2
Branch roots, seeming regularity in formation of 24
Breathing roots 25
Buckling of the fruit bunch 67
Bud, development of new leaves in 40
Bud, flowering 30
Bud, vegetative 30
Bud, vegetative, development of 84
"Bud rot" disease 42
Burning forest for planting 116

PAGE
Buffaloes as draught animals ... 138
Bullocks as draught animals ... 138
Butterfly, coconut "skipper" ... 148

C

"Cabbage" ... 30, 39, 84
"Cadjan" ... 48
Cafea robusta ... 152
Cajanus indicus ... 157
Cake, coconut ... 77
Calcium (see lime).
Catch crops ... 149
Catch crops, pulses as ... 151
Care of young plantation ... 142
Cattle manure ... 204
Centrosema plumerii ... 158
Charcoal, manufacture of from coconut shell ... 243
"Chekku" oil mill ... 227
Coconut, a light-demanding tree ... 153
Coconut cake ... 77
Coconut, dwarf varieties of ... 53
Coconut, elevation suitable for ... 95
Coconut fruit, economic uses of ... 76
Coconut oil ... 76, 226
Coconut oil as an export commodity ... 226
Coconut oil, manufacture of ... 226
Coconut oil, manufacture of from fresh meat ... 227
Coconut palm, adaptability of ... 87
Coconut products ... 217
Coconut, proximity of the sea for growth of ... 94
Coconut, range of temperature, suitable for ... 95
Coconut, red weevil ... 42
Coconut "skipper" butterfly ... 148
Coconut, soils suitable for ... 93
Coconut, the ... 75
Coconut timber ... 32
Coconut, varieties of ... 53
Coconut water ... 68, 75
Coffee ... 152
Coir ... 76
Coir, manufacture of ... 230
Coir fibre, colour of ... 230
Coir fibre, spinning of ... 232
Coir, manufacture of from fresh husk ... 233
Coir, retting of husk for manufacture of ... 230
Coir yarn, grading of ... 232
Colocasia ... 151
Colour analysis of roots ... 17, 18
Colour of coir fibre ... 230
Colour of ripe fruit ... 74

PAGE

Colour of roots ... 17
Colour of sclerenchyma cells in root ... 26
Colour variation in fruit ... 74
Contour survey, necessity of on undulating ground ... 118
Conveyance of nuts to dryer ... 167
Cool storage, possibility of for ocean transport of oil ... 229
Copeland ... 182
Copra ... 76
Copra, drying floors for sun-drying ... 219
Copra, drying kilns ... 222
Copra, estimation of yield as ... 225
Copra, hot air dryers for manufacture of ... 223
Copra, hygroscopicity of ... 224
Copra, keeping qualities of ... 221
Copra, manufacture of ... 218
Copra, manufacture, method of splitting nuts for ... 219
Copra, manufacture, suggested improvements in ... 223
Copra, protection against rain during manufacture of ... 221
Copra, quality of from germinated nuts ... 71
Copra, sun-drying of ... 218
Cover crops ... 154
Cover crops, on light soils ... 156
Cover crops, on heavy soils ... 156
Cover crops, requisites for ... 155
Cover crops, uses of ... 154
Cowpeas ... 150, 158
Cropping, leaf scars a guide to previous ... 32
Cross fertilization ... 4
Crown, the ... 34
Crown, compact ... 36, 97
Crown of a young tree, shape of ... 37
Crown of a bearing tree, shape of ... 37
Crown, moisture supply to ... 48
Crotolaria striata ... 157
Cultivation, effects of on soil ... 129, 132
Cultivation, effects of on root system ... 130
Cultivation, effects of on soil water movement ... 129, 133, 134
Cultivation, implements of ... 138
Cultivation, importance of ... 127
Cultivation, objects of ... 128
Cultivation, manual ... 144
Cultivation, systematic, an example of the results of ... 131
Cultivator, disc ... 140
Cultivator, types of ... 140
Cynodon dactylon ... 114

D

Damaged roots, repair to ... 25
Dead roots ... 16
Decline of tree, death of roots ... 16

PAGE
Definition of manuring 170
Depth of leaf scars 31, 32
Depth of sowing seed nuts 109
Development of bud or "cabbage" 84
Development of fruit 67, 170
Development of new leaves in the bud 40
Development of roots, effect of manures on 207
Development of root system in seedling 5
Development of shoot 80
Development of spadix 50
Direction taken by roots, variation in 3, 208
Direction of leaf spirals 38
Disc cultivator 140
Disease, "bleeding" 89
Disease, "bud rot" 42
Disease, *Pestalozzia palmarum* 35, 109, 148
Disposal of leaves, &c., in a plantation 159
Distance between trees 118, 120
Dolichos uniflorus 151
Dormant roots 2, 16, 24
Double transplantation of nursery seedlings 112
Drainage 87
Drainage in the tropics, definition of 87
Drainage, effects of bad natural drainage 88
Drainage for nursery 108
Drainage, natural, selection of land with good 89
Drainage, vegetation as a guide to 90
Draught animals in the tropics 138
Drought, effects of on the coconut palm 89
Drought, resistance of the coconut to 89
Dryers, hot air for copra manufacture 223
Drying floors for preparing sun-dried copra 219
Drying kilns for copra manufacture 222
Dry matter, percentage of to green weight in one-year-old tree ... 186
Dry matter, percentage of to green weight in two-year-old tree ... 186
Dry matter, percentage of to green weight in young tree 186
Dry matter, percentage of to green weight in bearing tree 186
Dry matter, percentage of to ash (see ash).
Duct, honey 68
Dwarf varieties of coconuts 53

E

Economic uses of coconut fruit 76
Economic uses of inflorescence 63
Economic uses of leaves 48
Economic uses of leaflets 49
Economic uses of stipules 49
Eleusine coracana 150
Elevation suitable for coconuts 95
Embryo 69, 78

PAGE

Endosperm, formation of ... 69
Enzymes in germinating nut ... 78
Epidermis of root ... 26
Erosion, checking of surface ... 159
Experiments, conduct of manurial ... 208, 209, 210
Export, coconut oil as a commodity of ... 226
"Eyes" ... 75
"Eye, soft" ... 69

F

"Feeding roots" ... 21
Female flower ... 51, 53, 55
Fertilization by insect agency ... 55, 65
Fibre, colour of coir ... 230
Fibre, extraction of from retted husk ... 231
Fibre, grading of ... 232
Fibre, other than coir ... 243
Fibre, stage of ripeness of the husk for the best quality ... 230
Fibre, spinning of ... 232
Filling blanks in field ... 112
First formed roots, downward tendency of ... 19
Flower cushion ... 51
Flower, female ... 51
Flower, female, causes of variation in setting of ... 58
Flower, female, proportion which set ... 58
Flower, female, variation in numbers of ... 62
Flower, male ... 51, 53, 55
Flower, scent of ... 55
Flowers, number of male and female ... 51
Flowers, order of opening ... 52
Flowers, sex determination of ... 60
Flowering branch ... 50, 51
Flowering branch, scars ... 30
Flowering branch, economic uses of ... 63
Flowering branch, buds ... 30
Flowering, duration of ... 52
Food supply for seedling in fruit ... 80
Forest land for planting ... 116
Formation of endosperm ... 69
Fruit, analyses of at different stages of development ... 173
Fruit, analyses of, grown in different countries ... 182, 183
Fruit, barren ... 66
Fruit branch, buckling of ... 67
Fruit, colour of ... 74
Fruit, cross section of ... 75
Fruit, development of ... 65, 67
Fruit, economic uses of ... 76
Fruit production, loss of plant food by ... 181
Fruit production, loss of plant food to the plantation by ... 182
Fruit, ripe, colour of the coat ... 74

PAGE

Fruit, shedding of ... 66
Fruiting branch scars ... 30
Fruiting, rate of effect on leaf development ... 35
Fungus, symbiotic in roots ... 25
Fungus (see disease).

G

Germ ... 69, 78
Germinated nuts, quality of copra from ... 71
Germinating nut, enzymes in ... 78
Germination of seed ... 78, 82
Germination percentage ... 106
Gland, honey ... 55
Good type of tree ... 99
Grading of coir fibre ... 232
Grading of coir yarn ... 232
Grains, pollen ... 54
Grass land for planting ... 114
Grown tree, root system of ... 22
Growth, effects of light on direction of ... 32
Growth, effects of wind on direction of ... 32
Growth of leaf, rate of ... 40

H

Habit, root ... 3
Hairs, absence of root ... 26
Hardening of the shell ... 69
Harvesting ... 162
Harvesting nuts for seed ... 105
Harvesting programme ... 162
Haustorium ... 78
Haustorium, colour of ... 81
Haustorium, starch stored in ... 80
Haustorium, structure of ... 79
Haustorium, sugar absorbed by ... 80
Healing of wounds ... 29
High forest land for planting ... 116
Hoeing ... 144
"Holing" ... 122
Honey duct ... 68
Honey gland ... 55
Horse gram ... 151
Hot air dryers ... 223
Husk ... 74
Husk, loss of plant food in the process of retting ... 234
Husk, retted, extraction of fibre from ... 231
Husk, retting of, for coir manufacture ... 230
Husk, stage of ripeness of, for best quality of coir ... 230
Husk, thickening of ... 74

PAGE

Husking nuts ... 168
Humus supply ... 144
Hygroscopicity of copra ... 224

I

Imperata grass ... 114
Implements of cultivation ... 138
Implements, types of to suit draught ... 139
Importance of stipules ... 39
Industries, minor ... 243
Inflorescence (see flowering branch).
Inflorescence, size of ... 56
Inner spathe ... 50
Insects, "Scale" ... 147, 109
Insect agency, fertilization of flowers by ... 55, 65
Internodes ... 30, 97
Irrigation of nursery ... 109
Irregular bearing trees ... 13

J

"Jaggery" ... 64
"Jaggery," manufacture of, from coconut sap ... 241
Jungle scrub for planting ... 115

K

Keeping qualities of copra ... 221
Kernel, composition of ... 76
Kernel, thickness of ... 75

L

"Lalang" grass ... 114
Land, classes of available for planting ... 114
Land, preparation of for planting ... 114
Land, selection of for planting ... 87
Lateral spread of roots, factors which influence ... 18
Leaf ... 43
Leaf arrangement ... 37-39, 98
Leaf arrangement, importance of ... 38
Leaf development, rate of ... 34
Leaf development, rate of, effects of fruiting on ... 35
Leaf development, rate of, effects of rainfall on ... 34
Leaf development, rate of, natural variation in ... 36
Leaf, economic uses of ... 48
Leaf growth, rate of ... 40
Leaf, length of life of ... 35
Leaf scars ... 30

PAGE

Leaf scars, depth of ... 32
Leaf scars, their relation to previous cropping ... 32
Leaf, size of ... 45
Leaf spirals, number of ... 38
Leaf spirals, direction of ... 38
Leaf stalk ... 43, 46
Leaf stalk, attachment of ... 43
Leaf stalk, shape of ... 44, 99
Leaf surface area, selection for ... 45
Leaf, weight of green ... 43
Leaflets ... 45, 48, 49
Leaflets, attachment of ... 47
Leaflets, effects of light on ... 48
Leaflets, length of ... 45
Leaflets, number of ... 45
Leaflets, width of ... 45
Leaves, &c., disposal of in a plantation ... 159
Leaves, normal number of, on a tree ... 36
Leaves, variation in number of ... 34
"Leggy" seedlings ... 106, 111
Lifting seedlings from the nursery ... 124
Light-demanding tree, the coconut palm ... 153
Light, effects of, on leaflets ... 48
Light, effects of, on direction of growth ... 32
Light requirements of a young tree ... 212
Lime, quantity in fruit at different stages of development ... 176, 180
Lime, requirements of the coconut for ... 200
Longevity of roots ... 17
Loss of plant food by fruit production ... 181

M

Magnesia in fruit at different stages of development ... 176, 180
Magnesia, requirements of the coconut tree for ... 200
Male flower ... 51, 53
Manihot ... 151
Manufacture of coconut oil from the meat ... 227
Manufacture of coir ... 230
Manufacture of coir from the fresh husk ... 233
Manufacture of copra ... 218
Manufacture of copra, methods of ... 218
Manufacture of copra, suggested improvements in ... 223
Manufactures, coir ... 232
Manure, application of ... 124, 206
Manure at the time of transplantation ... 123
Manure, definition of ... 170
Manure, cattle ... 204
Manure, effects of on root development ... 207
Manure for nursery ... 110
Manure, nitrogenous ... 206
Manure, phosphatic ... 204

PAGE

Manure, potassic ... 203, 206
Manurial resources of the plantation, utilization of ... 202
Manurial experiments, conduct of ... 208, 209, 210
Manuring ... 170
Margarine ... 77
Meally bug ... 65, 148
Meat, thickness of ... 75
Meat, composition of ... 76
Medicinal properties of the root ... 28
Methods of copra manufacture ... 218
Methods of oil extraction ... 226
Methods of picking nuts ... 163, 164
Methods of raising seedlings ... 111
Methods of sowing seed ... 108
Methods of spacing ... 120
Methods of splitting nuts ... 219
Methods of tapping ... 238
Methods of terracing ... 120, 121
Methods of transplanting ... 125
Methods of working a plantation ... 162
Mill, oil, the "Chekku" ... 227
Minor industries ... 243
Moisture, supply of, to the bole ... 48
Moisture, supply of, to the crown ... 48
Moulds, development of, on manufactured copra... 224
Movement of soil water ... 203
Mucuna utilis ... 158
Mulch, soil ... 143, 201

N

Natural drainage, essentials of ... 89
Natural variation in rate of leaf development ... 36
Nitrogen in fruit at different stages of development ... 174, 177
Nitrogenous manures ... 206
Norris ... 183, 241, preface
Normal number of leaves on a tree ... 36
Number of flowers male and female ... 51
Number of leaf spirals ... 38
Number of leaves on a tree ... 36
Number of leaves on a tree, variation in ... 24
Number of roots on a tree ... 12
Number of roots on a tree, irregular bearing ... 13
Number of roots on a tree, regular bearing ... 10
Nursery or seedbed ... 107
Nursery, drainage of ... 108
Nursery, manuring of ... 110
Nursery, method of sowing seed in ... 108
Nursery, season for sowing in ... 107
Nursery, selection of seedlings in ... 106
Nursery, shade for ... 108
Nursery, site of ... 108

PAGE
Nursery, spacing of seed nuts in the 108
Nursery, watering of 109
Nut, the 75
Nut, the beard of 79
Nut, conveyance of to dryer 167
Nut, harvesting of for seed 105
Nut, husking of 168
Nut, method of picking 163, 164
Nut, method of splitting for copra manufacture 219
Nut, shape of for seed 100
Nut, storage of in the husk 220
Nut, variation in size of 100

O

Ocean transport of oil, possibility of cool storage for 229
Œcophylla smaragdina 65, 147
Oil cake, coconut 77
Oil, coconut 76, 226
Oil, coconut, as an export commodity 226
Oil, coconut, extraction in the Philippines 226, 228
Oil, coconut, manufacture of from fresh meat 227
Oil, coconut, methods of extraction 226
Oil, coconut, ocean transport of 228
Oil, coconut, tariffs on 228
Oil mill, the "Chekku" 227
Opening of flowers, order of 52
Ornamental varieties of coconuts 53
Outer spathe 50
Oxen, draught 138

P

Palm, palmyra 235
Palm, sago 235
Palm sugar (see "jaggery").
Palm wine (see toddy).
Panicum repens 114
Peat soils 91
Pericycle 27
Period of flowering 52
Periodicity in flowering and setting 59
Percentage, germination 106
Pestalozzia palmarum 35, 109, 148
Peteole (see leaf stalk).
Phaseolus lunatus 158
Phosphates, percentage in ash in one-year-old tree 189
Phosphates, percentage in ash in two-year-old tree 189
Phosphates, percentage in ash in young tree 189
Phosphates, percentage in ash in bearing tree 189
Phosphates, quantity in fruit at different stages of development 175, 179

PAGE

Phosphates, requirements of coconut tree for ... 199
Phosphatic manures ... 204
Philippines, oil extraction in the ... 226, 228
Phyllotaxis ... 38, 98
Picking nuts, methods of ... 163, 164
Pits, planting, size of ... 123
Plantation management ... 159
Plantation, old, management of ... 212
Plantation, selection of site for a ... 87
Plantation, spacing of trees in a ... 118, 120
Plantation refuse, burning of ... 161
Plant food, loss of by fruit production ... 181
Plant food, loss of by fruit production to the estate ... 182
Planting closely, effects of ... 119
Ploughs, types of ... 139
Plumule ... 78
Pollen grains ... 54
Pollen, shedding of ... 54
Pollination ... 52, 54
Pollination, artificial ... 54, 104
"Poonac" ... 77
Potash in fruit at different stages of development ... 175, 178
Potash, percentage in ash in a one-year-old tree ... 188
Potash, percentage in ash in a two-year-old tree ... 188
Potash, percentage in ash in a young tree ... 188
Potash, percentage in ash in a bearing tree ... 188
Potash, requirements of the coconut tree for ... 197
Potassic manures ... 203, 206
Products of the coconut palm ... 217
Products of the coconut coir ... 232
Programme for harvesting ... 162
Prudholme ... 75
Pruning of roots ... 28
Pulses as catch crops ... 151

Q

Quality of coir ... 233
Quality of copra from germinated nuts ... 71

R

Raggi ... 150
Rain, effects of on drying copra ... 218
Rain, protection against when drying copra ... 221
Rainfall, effects of on rate of leaf development ... 34
Rancidity of oil, a cause of ... 229
Range of root system ... 18
Rate of leaf development ... 34
Rate of root production ... 3
Red ant (see *Œcophylla smaragdina*).

PAGE
Red coconut weevil ... 42
Regeneration ... 212
Register, bearing ... 102, 103
Regular bearing tree, root development of ... 10
Resistance to drought of the coconut palm ... 89
Retted husk, extraction of fibre from ... 231
Retting husks for coir manufacture ... 230
Retting husks, loss of plant food during the process of ... 234
Rhinoceros beetle ... 41, 110, 144, 145, 161, 165
Rice, dry land ... 150
Ripeness of nut and oil percentage ... 72
Ripeness of nut, stage of, for quality of coir ... 230
Ripeness of nut, testing for ... 71
Ripeness of nut, time of ... 70, 163
Root cap ... 26
Root, colour of an indication of its age ... 17, 18
Root development, effects of manuring on ... 207
Root development, effects of soil aeration on ... 3
Root development, influence on bearing capacity ... 4, 10
Root, epidermis of ... 26
Root habit ... 3
Root hairs, absence of ... 26
Root-producing area of the bole ... 6
Root production, rate of ... 3
Root production, variation in rate of in seedlings ... 6, 7, 8
Root production, variation in rate of in young trees ... 8, 9
Root pruning ... 28
Root scars ... 16
Root system, effects of cultivation on ... 130
Root system, necessity for a well developed ... 201
Root system of a grown tree ... 22, 92
Root system of a young tree ... 20
Rootlets, branch ... 2
Roots, absorptive area of ... 1, 26
Roots, astringency of ... 28
Roots, branch ... 2
Roots, branching, variation in ... 3
Roots, branch, seeming regularity in their formation ... 24
Roots, breathing ... 25
Roots, colour of ... 17
Roots, damaged, repair of ... 25
Roots, dead ... 16
Roots, direction of, variation in ... 3, 208
Roots, direction of growth, variation in seedlings ... 6
Roots, dormant ... 2, 16 24
Roots, "feeding" ... 21
Roots held in reserve ... 2
Roots, lateral spread of, factors which influence ... 18
Roots, longevity of ... 17
Roots, medicinal properties of ... 28
Roots, number of ... 1, 2
Roots, number of, on an irregular bearing tree ... 13

PAGE
Roots, number of on a regular bearing tree 10
Roots, production of from abnormal areas 18
Roots, symbiotic fungus in 25
Roots, structure of 26
Roots, thickness of 1
Roots, vertical spread of, factors which influence 19
Roots, "water" 21
Roots, "water," importance of 22

S

Saccharum spontaneum 114
Sago palm 235
Sap, variation in flow of when trees are tapped 236
Scale insects 109, 147
Scars, flowering branch 30
Scars, leaf 30
Scars, root 16
Scent of flower 55
Sclerenchyma cells 26
Sclerenchyma cells, colour of 26
Sea, proximity to, for planting coconuts 94
Seasonal variation in yield 61, 99
Season for sowing in the nursery 107
Seasoning of coconut timber 33
Seed 75
Seed and seed selection 96
Seed bed or nursery 107
Seed coat 75
Seed, depth of sowing 109
Seed, germination of 78, 82
Seed, harvesting nuts for 105
Seed, method of sowing in nursery 108
Seed purposes, selected trees for 101
Seed rate 106
Seed selection, age of tree for 96
Seed selection, for thickness of husk 100
Seed, sowing of in situ 107
Seed, spacing of in nursery 108
Seedlings, age of for transplanting 110
Seedlings, cause of variation in 53
Seedlings, development of root system of 5
Seedlings, food supply for, in fruit 80
Seedlings, lifting of from nursery 124
Seedlings, "leggy" 106, 111
Seedlings, root system of 19
Seedlings, selection of in nursery 106
Seedlings, one year old, percentage of dry matter to green weight ... 186
Seedlings, one year old, percentage of ash to dry matter 187
Seedlings, one year old, percentage of lime to total ash 190
Seedlings, one year old, percentage of magnesia to total ash 191

PAGE
Seedlings, one year old, percentage of phosphoric acid to total ash... 189
Seedlings, one year old, percentage of potash to total ash 188
Seedlings, two years old, percentage of dry matter to green weight... 186
Seedlings, two years old, percentage of ash to dry matter 187
Seedlings, two years old, percentage of lime in total ash 190
Seedlings, two years old, percentage of magnesia in total ash ... 191
Seedlings, two years old, percentage of phosphoric acid to total ash... 189
Seedlings, two years old, percentage of potash to total ash 188
Seedlings, variation in direction of roots of 6
Seedlings, variation in rate of root production of 6
Seed nut, shape of 100
Selected trees for seed purposes 101
Selection of land for good drainage 89
Selection of seedlings for area of leaf surface 45
Selection of seedlings in nursery 106
Selection of site for a plantation 87
Sensitive plant 157
Setting of female flowers, proportion of 58
Sex of flower, determination of 60
Sex of flower, causes of variation in 58
Shade for nursery 108
Shape of leaf stalk 44, 99
Shape of leaf stalk, necessity for selection for 44
Shape of seed nut 100
Shedding of fruit 66
Shedding of pollen 54
Shell 75
Shell, hardening of 69
Shell, coconut, manufacture of charcoal from 243
Shoot, development of 80
Site for nursery, selection of 108
Site for plantation, selection of 87
Size of nuts, variation in 100
Soft "Eye" 69
Soil aeration 202
Soil aeration, effects of, on root development 3
Soil aeration, effects of cultivation on 129
Soil mulch 143, 201
Soil water movement 23, 87, 203
Soils, alkaline 91
Soils, peat 91
Soils suitable for coconuts 93
Sowing (see nursery).
Sowing, depth of 109
Sowing seeds in situ 107
Spacing trees in plantation 118, 120
Spacing trees on undulating ground 120
Spacing seed in nursery 108
Spadix, development of 50
Spathe, bursting of 51
Spathe, inner 50
Spathe, outer 50

PAGE
Spikelet ... 51
Spinning coir fibre ... 232
Sporosa lindleyana ... 230
Sprays, Bordeaux-resin-soda mixture ... 148
Stagnant water, effects of, on root system ... 19
Stamens ... 54
Stem ... 29, 97
Stem, arrangement of vascular bundles in ... 32
Starch stored in haustorium ... 80
Stigma ... 55
Stipules, economic uses of ... 49
Stipules, importance to the tree of ... 39
Storage of nuts in the husk ... 220
Structure of the root ... 26
Sugar, palm ... 64
Sugar palm, manufacture of from "toddy" ... 241
Sugar, absorption of, by haustorium ... 80
Sun-drying of copra ... 218
Sun-drying of copra, protection against rain during ... 221
"Supply seedlings" ... 112
Sweet potato ... 151, 158
Sweet toddy ... 235
Symbiotic fungus in roots ... 25

T

Tapioca ... 151
Tapping ... 235
Tapping, an hereditary occupation ... 236
Tapping, art of ... 236
Tapping, effects of on subsequent yield of fruit ... 237
Tapping, methods of ... 238
Tariffs on oil ... 228
Temperature, range of suitable for coconuts ... 95
Tephrosia candida ... 157
Termites (see white ants).
Terracing, methods of ... 120
Thickness of husk ... 74
Thickness of husk, seed selection for ... 101
Thickness of meat ... 75
Thickness of roots ... 1
Timber, coconut, seasoning of ... 33
Timber, coconut, uses of ... 33
Time taken for nuts to mature ... 70
"Toddy" ... 64, 235
"Toddy," manufacture of sugar from ... 241
"Toddy," sweet ... 235
"Toddy," yields of ... 238
Transplantation, double, of nursery seedlings ... 112
Transplanting, manuring at the time of ... 122
Transplanting, age of seedlings for ... 110

PAGE

Transport of oil ... 228
Transport of oil, possibilities of cool storage for ... 229
Tree, young, bad type of ... 111
Tree, young, good type of ... 111
Tree, young, light requirements of ... 212
Tree, bearing, percentage of dry matter to green weight ... 186
Tree, bearing, percentage of ash to dry matter ... 187
Tree, bearing, percentage of lime in ash ... 190
Tree, bearing, percentage of magnesia in ash ... 191
Tree, bearing, percentage of phosphates in ash ... 189
Tree, bearing, percentage of potash in ash ... 190
Tree, young, percentage of dry matter to green weight ... 186
Tree, young, percentage of ash to dry matter ... 187
Tree, young, percentage of lime in ash ... 190
Tree, young, percentage of magnesia in ash ... 191
Tree, young, percentage of phosphates in ash ... 189
Tree, young, percentage of potash in ash ... 190
Type of good tree ... 99
Type of bad tree ... 99

U

Underplanting ... 212
Undulating land, necessity for contour survey on ... 118
Undulating land, spacing on ... 120
Undulating land, terracing on ... 120
Utilization of manurial resources of the plantation ... 202

V

Varieties of coconuts ... 53
Varieties of coconuts, dwarf ... 53
Varieties of coconuts, ornamental ... 53
Varieties of coconuts with edible husk ... 74
Variation in colour of fruit ... 74
Variation in direction in first formed roots of seedling ... 6
Variation in direction taken by roots ... 3, 208
Variation in number of female flowers ... 62
Variation in number of leaves on a tree ... 34
Variation in rate of flow of sap from tapped trees ... 236
Variation in rate of root production in seedling ... 6-8, 80
Variation in rate of root production in young tree ... 8
Variation in size of nut ... 100
Variation in type of tree, causes of ... 53
Variation in seasonal yield ... 61, 99
Vascular bundles, arrangement in leaf stalk ... 47
Vascular bundles, arrangement in stem ... 32
Vascular system of the root ... 27
Vegetation as a guide to natural drainage ... 90
Vegetative bud ... 30, 39
Vertical spread of roots, factors which influence ... 19

PAGE
Vigna catyang ... 150, 158
Vinegar from palm arrack ... 242

W

Walker ... 183
Water movement in soil ... 23, 87, 203
Water movement in soil, effects of cultivation on 132-138
"Water roots" ... 21
"Water roots," branching of ... 21
"Water roots," importance of ... 22
"Water," coconut ... 68, 75
Watering nursery ... 109
Wash, checking of surface ... 159
Weeds, annual, destruction of ... 142
Weeds, perennial, destruction of ... 145
Weeding, importance of ... 128
Weevil, red coconut ... 42
Weight of green leaf ... 43
White ants ... 110
Wind, effects of on direction of growth ... 32
Wood, coconut ... 32
Wounds, healing of ... 29

Y

Yarn, grading of coir ... 232
Yield, estimation of, as copra ... 225
Yield of nuts, effects of tapping on ... 237
Yield, seasonal variations in ... 61, 90
Young plantation, care of ... 142
Young tree, light requirements of ... 212
Young tree, root system of ... 20
Young tree, variation in the rate of root production in ... 8

LONDON:
JOHN BALE, SONS & DANIELSSON, LTD.,
83-91, GREAT TITCHFIELD STREET, OXFORD STREET, W. 1.